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ON THE SPECTRUM OF RADIUM.

By C. RUNGE.

M. AND MME. CURIE have discovered that certain substances prepared from pitch blende possess the remarkable property of emitting Becquerel rays. There is good reason to believe this property to be connected with the existence of at least one new element. For in the spectrum of one of these substances M. Demarçay has found a number of lines, which cannot be identified with any known lines.[1] I think, however, that his determinations of the wave-lengths can hardly be considered sufficiently accurate for the purpose of identification, and I have therefore tried to determine the wave-lengths with greater precision. Dr. F. Giesel kindly gave me a preparation that he has made of the substance in question. The new element is present only in very minute quantities, for it has not yet been possible to prove its existence by any chemical means. Apart from the new element the substance consists of chloride of barium. Of M. Demarçay's fifteen radium lines I could not observe more than three. The remaining twelve either do not appear, or they so nearly coincide with lines which I observed in the spectrum of pure chloride of barium, that I could not convince myself of their existence. I do

[1] DEMARÇAY, *C. R.*, 129, 717, 1899.

not want to imply that these lines in M. Demarçay's list do not belong to the new element. I merely wish to say that I have not been able to check his observations of them. It may be that M. Demarçay produced the spectrum in a different manner, thereby getting rid of the lines, which in my comparison spectrum of pure chloride of barium take the place of the radium lines. The following list contains M. Demarçay's determinations as well as mine, together with some remarks on the different lines:

Runge		Demarçay		Remarks
Wave-length	Mean error	Wave-length	Intensity	
		3649.6	12	Also in $BaCl_2$.
3814.591	0.016	3814.7	16	
		4340.6	12	Not seen.
		4364.2	3	" "
		4436.1	8	" "
		4458.0	3	" "
		4533.5	9	" "
		4600.3	3	Also in $BaCl_2$. Kayser and Runge: *Ba* 4600.02
		4627.4	4	" " " " " " 4628.45
		4641.9	4	" " "
4682.346	0.009	4683.0	14	
		4692.1	7	" " " " " " 4691.74
		4699.8	3	" " " " " " 4700.64
		4726.9	5	" " " " " " 4726.63
4826.14	0.06	4826.3	10	

The relative intensities of the three lines which I have observed agree with the estimations of M. Demarçay. His absolute intensities have probably been greater. That would explain why he has seen lines that did not appear in my spectrum. I cannot, however, explain why the lines 4340.6, 4436.1, 4533.5, to which he assigns the intensities 12, 8, 9, were not seen by me, as the line 4826 (intensity 10) is clearly visible.

In the second column I have added the mean error of my determinations. The first line was only photographed in the first order of a grating of 1 meter radius and about 50,000 lines. The second and third lines have also been photographed in the first order of a large grating of about 6 meters radius and 110,000 lines. The third line has also been photographed in the second order of the small grating. The wave-lengths were interpolated

partly from barium lines, partly from iron lines. Iron wire was for this purpose substituted for the platinum wire carrying the substance. I have photographed the spectrum from 6000 A. U. to 2400 A. U. The red part of the spectrum was examined visually.

The three lines are not among the Fraunhofer lines measured by Rowland. 4826.14 falls between 4825.907 and 4826.554; 4682.346 between 4682.295 *Fe?* and 4682.529 *Co;* 3814.591 between 3814.500 *C* and 3814.671 *Fe-C.*

The platinum wire which was to carry the substance to be investigated, was doubled up and twisted into a loop. By letting an electric current flow through the wire it was heated sufficiently to make the substance stick to the loop and melt together. This is a far more economical way of fixing the substance to the wire than by heating it in a Bunsen flame. I could make a series of exposures and an elaborate examination of the red part of the spectrum with not more than 0.1 gram. At the same time this arrangement serves to heat the substance during the exposure, which materially increases the intensity of the spectrum. I have to thank Professor Paschen for suggesting this device. The substance was taken as anode. The kathode is then also heated by properly adjusting a second spark-gap interposed in the circuit. In this way the air lines may be gotten rid of.

I have also heated the radium preparation *in vacuo* in order to search for an unknown gas. The spectrum was that of chlorine with some sulphur lines showing as an impurity, but no new lines were observed. Another preparation with similar physical properties containing the hypothetical element "Polonium," which I also owe to the kindness of Dr. Giesel, was investigated in the same manner. But neither the spark spectrum nor the spectrum of the vacuum tube, when the substance was heated in it, showed any new lines.

The three radium lines, of which I have given the wavelengths, appeared also in a preparation of barium bromide which Dr. de Haen had the kindness to give me.

TECHNISCHE HOCHSCHULE, HANNOVER,
May 1900.

THE VELOCITY OF METEORS AS DEDUCED FROM PHOTOGRAPHS AT THE YALE OBSERVATORY.

By W. L. Elkin.

The instruments in use at the Yale Observatory for the photographic observation of meteors (see this Journal 9, 20) have been equipped with an arrangement for the determination of the velocity of the meteors. The idea of using photography for this purpose seems to have first been suggested as long ago as 1860 by J. Homer Lane, the well-known physicist and discoverer of "Lane's Law." In 1885 a well-planned attempt in this direction was made by Zenker, in Berlin, on the occasion of the expected shower of Andromedids, but without success, apparently. And lately the suggestion has been again made by Professor Fitzgerald.

The Yale apparatus consists of a wheel (a bicycle wheel) rotating in front of the cameras and carrying a number of opaque screens. There are at present 12 of these interceptors and the rotation is effected at the rate of 30 to 50 turns a minute by means of a small motor worked by 3 or 4 bichromate cells. It will be advisable to increase the number of occultations in future, however. At each revolution a record is made on the chronograph, so that the wheel's velocity at any instant is always known.

The length of the interruptions of a meteor trail and the resulting velocity are easily derived from the plates, of which Fig. 1 shows the first such divided-up trail secured (on July 31, 1899), if the meteor is also recorded on a plate at our second station at Hamden, distant about 3 km. The first attempt was made at this August period last year, and subsequent ones at the Leonid, Andromedid, and Geminid epochs in November and December last. In all, so far five such trails have been obtained with corresponding records at Hamden and the time and identification also secured. These have now been carefully measured

FIG. 1.

and reduced and the resulting data are brought together in the following table, of which the headings explain themselves sufficiently:

Meteor No.	Date 1899	Greenwich mean time	Apparent radiant 1875.0 R. A.	Apparent radiant 1875.0 Decl.	Apparent velocity (km per sec)	Approximate altitude (in km)
1	July 31	$17^h\ 4^m\ 30^s$	28° 55′	+57° 31′	50.4	From 88 to 75
2	Aug. 7	14 25 25	288 12	− 6 20	12.2	50 45
3	Aug. 8	16 32 47	43 55	+56 33	50.3	101 94
4	Nov. 24	16 31 25	27 43	+40 33	20.2	93 90
5	Dec. 12	21 43 0	113 44	+33 36	36.5	90 86

If we now correct the values for the apparent radiant and velocity for the effect of the attraction of the Earth and its diurnal rotation by Schiapparelli's formulae, we derive the "corrected" radiant and velocity in the following table, and hence the "true" velocity of the meteor relative to the Sun. The last columns of this table contain the "true" and "apparent" velocities which a parabolic orbit or, in the case of the November 24 meteor, an elliptic orbit of 6.62 years period should have produced.

Meteor No.	Corrected radiant, 1875.0 R. A.	Decl.	Corrected apparent velocity (km per sec.)	True velocity (km per sec.)	Parabolic or elliptic velocity (km per sec.) true	apparent
1	29° 50′	+57° 40′	49.1	34.4	41.8	58.3
2	289 44	−27 58	5.0	32.0	41.8	27.1
3	45 12	+56 35	49.0	32.4	41.8	60.3
4	23 52	+39 46	16.8	39.8	39.3	19.6
5	112 22	+33 2	34.7	34.0	42.4	49.5

A comparison of these last two columns with the corresponding ones of the observed values shows that, except in the case of the Andromedid meteor on November 24, both the apparent and true observed values of the velocity are much smaller than those derived on the assumption of a cometary velocity. The former (the observed) velocities lead to orbits of a very improbable character, having periods of from 1.25 to 1.80 years, so that it would seem an almost certain conclusion that the atmospheric retardation has amounted to from 8 to 15 km per second for the four meteors. On the other hand, the Andromedid on November 24 furnishes the following orbit, by the side of which is placed that of Biela's comet according to Hubbard;

$$\text{Meteor Nov. 24, 1899}: \begin{cases} \pi = 108^\circ\ 48' \\ \Omega = 242\ \ 22 \\ i = \ 12\ \ 4 \end{cases} 1875.0 \qquad \begin{cases} e = 0.7923 \\ a = 4.110 \end{cases}$$

$$\text{Biela Comet}: \begin{cases} \pi = 109^\circ\ \ 8' \\ \Omega = 245\ \ 51 \\ i = \ 12\ \ 33 \end{cases} 1852.0 \qquad \begin{cases} e = 0.7559 \\ a = 3.526 \end{cases}$$

Rather unfortunately this Andromedid trail is at the very edge of the plate and therefore somewhat ill-defined, so that the length of the single interruption available is somewhat uncertain. If this be changed by 19″ from the original measurement, or about one fifteenth of a millimeter on the plate, a quantity which perhaps is admissible under the unfavorable circumstances, an

exact agreement with the cometary elements a and e can be brought about.

This remarkable circumstance makes it therefore again somewhat questionable whether the small velocities found for the other four meteors may not after all be somewhere near the cosmic values and the truth will have to await accumulated evidence. Especially valuable will be a long trail with considerable change in altitude and a large number of sharp interruptions. The only one of our trails which has more than two such breaks is the one on August 7, where three values of the velocity can be deduced. These are, in the order of the meteor's progress and descent, 12.33, 12.11, and 12.09 km per second, which, while showing an increase of retardation, hardly admit of any very definite conclusion. As I have just said, more data are necessary and these we hope to secure and also increase their accuracy in the near future.

SOME NEW FLUORESCENCE AND AFTERGLOW PHENOMENA IN VACUUM TUBES CONTAINING NITROGEN.

By PERCIVAL LEWIS.

I. FLUORESCENCE.

WHILE investigating the effect of impurities on the spectrum of nitrogen, I observed some peculiar fluorescent and afterglow effects, which appear to be due to the presence of exceedingly small traces of oxygen or water vapor, and which apparently have not been previously described.

The nitrogen was chemically prepared by heating a solution of ammonium sulphate and sodium nitrite. The gas was freed from oxygen by passing it through a solution of pyrogallol. Sometimes the conditions were varied without change of the results, by passing it over heated copper. It was then carefully dried by passing it through concentrated sulphuric acid and a series of tubes containing calcium chloride, caustic potash, soda lime, and phosphorous pentoxide.

The vacuum tube usually employed was of the end-on type, with a quartz window, and could be used with either internal or external electrodes.

After pumping out and admitting first nitrogen, a remarkable fluorescence was observed during a few seconds after first closing the current. This fluorescence (which I shall call "β-fluorescence") was not limited to the path of the discharge, as in the case of the ordinary ("α") fluorescence, but was visible for some distance on each side of the electrodes where no discharge could be seen. This fluorescence flickered unsteadily for several seconds, then died away, first in the capillary, then in the more distant parts of the tube. The weaker the current, the longer the phenomenon lasted. It persisted steadily during the passage of a slow current of fresh nitrogen through the tube,

and was visible at pressures as high as 15 or 20 centimeters. At such pressures the phenomenon was often confined to the region of the electrodes, no visible discharge passing between them. If the tube was filled with fresh gas and the current rapidly turned on and off, the fluorescing regions could be seen gradually receding into the supply and exhaust tubes, as though some progressive change, due to the current, was taking place.

It was really fluorescence of the gas, not any direct radiation from the gas. This was proved by heating a portion of the tube. On admitting a slow stream of nitrogen, the tube did not fluoresce at the heated portion, although it did so strongly on both sides. The β-fluorescence gives a brilliant opalescent blue-green light, comparable in intensity with the fluorescence excited by cathode rays.

When the nitrogen was not freed from the last traces of oxygen, the β-fluorescence was considerably weaker. The addition of very small quantities of oxygen, hydrogen, water vapor, or carbon dioxide weakened or destroyed it.

It seemed possible that the fluorescent condition might be made permanent by complete drying and removal of every trace of oxygen. The most careful attempts in this direction failed to increase the duration of the phenomenon in the slightest degree. It seemed probable, therefore, that the β-fluorescence is not a property of absolutely pure nitrogen, but is due to small traces of some impurity or to chemical action.

In nitrogen prepared from air by passing through pyrogallol, and over hot copper and phosphorus, only the ordinary α-fluorescence could be seen. If, in addition, the air was allowed to rest some time in contact with copper turnings moistened with ammonia (a method strongly recommended by Threlfall[1]), a very feeble β-fluorescence could be seen. Either the oxygen had not been completely removed, or argon and other constituents of the air hindered the effect. The ordinary fluorescence was especially strong in air nitrogen, but it was not so strong as the β-fluorescence, was confined to the region

[1] THRELFALL, *Phil. Mag.*, (5), **35**, 1, 1893.

between the electrodes, and was diminished, not increased, during the passage of a current of fresh gas.

Morren[1] has described a very brilliant fluorescence which he observed in nitrogen tubes containing mercury vapor, which he ascribed to the ultra-violet radiation of the mercury. In my experiments the mercury vapor was usually excluded by a sulphuric acid valve. Its admission seemed to have no effect on the phenomenon.

It seemed certain that the β-fluorescence was due to some kind of radiation which the nitrogen emitted only during certain temporary conditions; therefore a complete investigation of the spectrum was undertaken.

During fluorescence the intensity of the entire visible spectrum was considerably diminished. No other change could be detected. Since steady fluorescence could only be obtained during the passage of a stream of fresh gas, involving change of luminosity due to the change in pressure, photometric measurements were difficult. It was roughly estimated, however, that the reduction in intensity during the β-fluorescence was certainly more than one half. At very high pressures the visible discharge disappeared almost completely.

An investigation of the ultra-violet region was next undertaken. The tube was provided with a quartz window, and by means of a quartz prism and lenses a short spectrum was thrown on a bariumplatinocyanide screen. Under ordinary conditions, when the current passed, a short visible spectrum and five bright fluorescent bands in the adjacent ultra-violet could be seen on the screen, with a very feeble and diffuse fluorescence in the extreme ultra-violet. When fresh nitrogen was admitted, the β-fluorescence took place, the visible spectrum vanished almost completely, and a number of bright bands flashed out with a maximum intensity far in the ultra-violet. When the stream of gas was cut off, the spectrum resumed its original appearance.

Photographs of the ultra-violet region were then taken under different conditions. In each case the time of exposure was

[1] MORREN, *Ann. Chim. et Phys.* (4), 4, 296, 1865.

two minutes, and corresponding pairs were taken respectively during and after the β-fluorescence, at an average pressure of 2 cm, and with the same current in each case. It was, of course, impossible to focus on all parts of the spectrum simultaneously, and after necessary disturbances of position it was impossible to reproduce the adjustments exactly; therefore all parts of the same photograph are not equally sharp, and no two sets of photographs show the bands in exactly coincident position. The wave-lengths of the edges of the bands were determined by comparison with the spectra of cadmium and zinc and with the map given by Deslandres.[1]

Below are data referring to the photographs obtained.

I. With internal electrodes and feeble current. (1) During β-fluorescence. The bands of wave-length 260, 248, and 237 $\mu\mu$ are the most intense. The visible spectrum fails to make any impression on the plate. (2) After the β-fluorescence had ceased. A portion of the visible spectrum can be seen, and the most intense bands are those of wave-length 358 and 337 $\mu\mu$. The bands in the extreme ultra-violet are much weaker. There are bands at $\lambda 227$ and $\lambda 215\,\mu\mu$, which made scarcely any impression on the plate.

II. External electrodes. Similar effects are observed, but the contrast is even stronger than when internal electrodes were used. In some photographs the extreme ultra-violet bands could not be seen at all except during β-fluorescence.

III. Nitrogen from air. The entire spectrum is more intense, as a stronger current was used. Otherwise there is no apparent difference from I (2).

IV. A Tesla coil was used. The contrast between the two conditions of the nitrogen is strongly shown.

V. In order to certainly remove all traces of oxygen and water vapor metallic sodium was sealed in the tube and heated. No β-fluorescence could then be obtained, and the extreme ultra-violet bands almost disappeared, as shown in the last pair of

[1] DESLANDRES, *Comptes Rendus*, 101, 1256, 1885; *Ann. Chim. et Phys.* (6), 5, 46, 1888.

photographs. The first was taken with a slow current of fresh nitrogen passing through the tube, the second with the nitrogen at rest.

The conclusion seems justified that the β-fluorescence is caused by the temporary emission of powerful ultra-violet radiation. It may possibly be due not altogether to the presence of this radiation, but to the absence or weakness of visible radiation. In III the extreme ultra-violet bands are almost as strong as in I (1); but the visible radiation is much stronger, and there is no β-fluorescence.

Deslandres[1] found that the nitrogen spectrum consists of three groups of bands, differing in their physical conduct. The first lies in the visible region, and, according to Deslandres, belongs to pure nitrogen. The second lies between 500 and 280 $\mu\mu$; the third between 300 and 200 $\mu\mu$. He found that after metallic sodium had been introduced into the tube and heated, the third group disappeared, while the second became stronger. He concluded, therefore, that the second group is due to a combination of nitrogen with hydrogen, the third to a combination of nitrogen with oxygen. The water which adheres so persistently to the walls of a glass tube is given off and decomposed by the current, and thus the components of the two combinations are supplied. If sodium be present the oxygen is removed, and the third group disappears.

My experiments and those of Deslandres seem to be closely related. It will be seen that Deslandres' third group coincides exactly with the regions of the spectrum which seem to excite the β-fluorescence. After sodium had been heated in the tube the β-fluorescence disappeared completely. When external electrodes were placed on the supply and exhaust tubes, some distance from the sodium, the glass in the region of these electrodes fluoresced brilliantly during the passage of a current of the fresh gas. It is evident, therefore, that no permanent change in the gas had been caused as it passed the hot sodium. It does not seem likely that any direct action or combination

[1] DESLANDRES, *loc. cit.*

between the nitrogen and sodium could destroy the β-fluorescence, and Deslandres' explanation seems very probably correct. We may assume that infinitesimal traces of the ever-present water are decomposed, and that the combination of the resulting nascent oxygen with the nitrogen takes place with so much energy that the atoms or molecules which take part temporarily emit a disproportionately large part of the radiation. If this be the correct explanation, however, it seems most singular that greater, but still very small, quantities of oygen or water vapor will completely destroy the β-fluorescence. The presence of the small quantity of the oxide of nitrogen formed during the first few seconds of discharge must also destroy the fluorescent action.

II. AFTERGLOW.

Morren,[1] Sarasin,[2] Warburg,[3] and others, have studied the afterglow in nitrogen which is due to the presence of small quantities of oxygen. Usually this phenomenon is described as a whitish, shimmering cloud. Sarasin[4] has also observed a yellow phosphorescence in nitrogen, which he attributed to an oxide of nitrogen. I have found but few references to the spectrum of the afterglow. Using electrodeless tubes, J. J. Thomson[5] found an afterglow in air with a spectrum consisting apparently of lines or bands. Hertz[6] could not obtain any spectrum of the afterglow in nitrogen; in air he observed a continuous spectrum, especially strong in the red, yellow, and green. Goldstein[7] observed a yellow afterglow in air; he makes no reference to its spectrum.

With considerable traces of oxygen in nitrogen I have obtained the white afterglow, with an apparently continuous spectrum. In nitrogen prepared from air, before the oxygen had been completely removed, I have also observed an apple-green

[1] MORREN, *Ann. Chim. et Phys.* (4), p. 293, 1865.

[2] SARASIN, *Pogg. Ann.*, 140, 425, 1870.

[3] WARBURG, *Arch. de Gen.* (3), 12, 504, 1884. [4] SARASIN, *l. c.*, p. 432.

[5] J. J. THOMSON, *Phil. Mag.*, 32, 335, 1891. [6] HERTZ, *Wied. Ann.*, 19, 78, 1883.

[7] GOLDSTEIN, *Verhand. d. deutscher phys. Gesell.*, 1, 16, 1883.

afterglow, with spectrum continuous in the green. I suspect that this was due to carbon dioxide from the pyrogallol solution. It was seen but once and could never be reproduced.

After chemically prepared nitrogen had been freed from the last traces of oxygen, I observed no afterglow in it when an ordinary induction current was used. After a condenser and spark gap had been introduced into the secondary circuit, however, a beautiful chamois-yellow mist filled the entire tube, and pulsated several centimeters into the connected tubes. On breaking the current, a bright afterglow lasted several seconds. At high pressures the thin white spark between the electrodes was surrounded by a sheath of this yellow, pulsating cloud.

Viewed through a pocket spectroscope of small dispersion, the spectrum consisted of three bright bands in the red, yellow (double), and green, and some weak lines in the red. The double yellow band was by far the brightest. Seen through a spectroscope of high dispersion, these four bands appeared weak and diffuse. The wave-lengths of their centers were approximately:

6240 5780 5740 5410

These bands seemed nearly or quite coincident with four bands of the nitrogen spectrum. At high pressures there were three maxima of the nitrogen spectrum in the region of these bands.

After the tube had been thoroughly desiccated with heated sodium, the afterglow vanished. It could not be obtained in nitrogen prepared from air.

This phenomenon seems likewise to depend on the presence of exceedingly small traces of water vapor or oxygen.

This afterglow seems to differ from those previously observed in the following respects: (1) It is produced only with condenser and spark gap; (2) it is seen only in nitrogen almost perfectly freed from oxygen; (3) the spectrum is banded, not continuous.

These experiments indicate not only that infinitesimal traces of a foreign substance can appreciably affect the spectrum of a

gas, but that these effects may be feebler, or altogether vanish when greater, but still small, quantities of the substance are present. Whether this action is the result of chemical activity or of disturbed electrical conditions, remains to be explained. One is reminded of the extraordinarily great influence of the presence of traces of moisture or oxygen on the cathode fall in nitrogen and hydrogen found by Warburg.[1] A direct connection between the two classes of phenomena is, however, difficult to trace. The effect of water vapor and oxygen on the spectrum of both hydrogen and nitrogen was to reduce the luminosity. The action of these substances on the cathode fall in hydrogen was opposite to its effect on that in nitrogen.

I take this occasion to thank Professor Warburg for his advice and help during this investigation.

BERLIN PHYSICAL INSTITUTE,
March 1900.

[1] WARBURG, *Wied. Ann.*, **31**, 562, 566, 590, 1887.

THE EFFECT OF SOME IMPURITIES ON THE SPECTRA OF SOME GASES. II.

By PERCIVAL LEWIS.

I. HYDROGEN (*Continued*).

IN a previous paper[1] the effects of small quantities of mercury vapor and other substances on the spectrum of hydrogen were described. The discharge tubes used in those experiments were provided with external electrodes. In later experiments internal electrodes were employed, these being made of iron in order to prevent amalgamation with the mercury vapor. As previously, the hydrogen was generated electrolytically and freed from traces of oxygen by being passed through an alkaline solution of pyrogallol. Observations were made (1) with closed secondary current, (2) with Tesla current, and (3) with condenser and spark gap in the secondary circuit. The luminosity of *Ha*, of the green mercury line, and of that part of the compound hydrogen spectrum lying adjacent to the mercury line was measured at different pressures of the hydrogen and temperatures of the mercury reservoir from which the vapor was supplied. The results are given in the following tables:

I. WITH CLOSED SECONDARY CURRENT.

Temperature of mercury reservoir, 1°.

Hydrogen pressure	Intensity		
	Ha	Compound	*Hg*
0.6	120	11	17
1	76	6	13
1.2	81	7	15
1.4	76	5	6
3.2	65	4	4
5.8	36	5	2
9	20	8	4
13	5	5	1

[1] LEWIS, this JOURNAL, **10**, 137, 1899; *Wied. Ann.*, **69**, 398, 1899.

I. WITH CLOSED SECONDARY CURRENT.—*Continued.*

Temperature of mercury reservoir 18°.

Hydrogen pressure	Intensity		
	Hα	Compound	*Hg*
0.5	81	9	51
1.3	61	5	34
3.2	49	8	36
4.8	36	5	15
12	3	2.5	4

The reduction in luminosity due to the presence of mercury vapor is quite noticeable, although not so great as when external electrodes were used. With primary current kept constant, no maximum of intensity was reached down to pressures of 0.5 mm. With external electrodes such a maximum was found at a pressure of 3 mm.

The spectrum obtained with the Tesla current was quite feeble, and the photometric measurements in consequence relatively less accurate. The effect of mercury vapor was quite marked. A maximum luminosity of both the hydrogen and the mercury spectrum was reached at a pressure between 1 and 2 mm.

II. TESLA CURRENT.

Temperature of mercury reservoir 1°.

Hydrogen pressure	Intensity		
	Hα	Compound	*Hg*
0.6	4.5	0.7	2.3
1.3	5.3	2	3.
3.5	3.1	0.7	1.8
7	1.5	0.5	1
19	0	0.5	Almost invisible
28	0	0.3	

Temperature of mercury reservoir 18°.

0.5	1.5	0.7	4.6
0.7	1.5	0.7	4.6
1.2	3.1	2	7.4
2.4	2	2	11
5	0.8	0.7	2.4
12	0.6	0.7	1.3

With a condenser and spark gap the discharge was too irregular to permit consistent measurements to be made. The effect of the presence of mercury vapor seemed hardly noticeable.

II. NITROGEN.

The influence of small quantities of mercury vapor, water vapor, and oxygen on the spectrum of nitrogen was also studied. The discharge tube had external electrodes. The previously used voltometer was replaced by a gasometer filled with nitrogen generated chemically by heating a solution of ammonium sulphate and sodium nitrite. The arrangement of apparatus was in other respects essentially the same as that used in the earlier experiments on hydrogen. The gas was freed from oxygen by passing it through an alkaline solution of pyrogallol.

The first photometric measurements showed great irregularity in the intensity of the nitrogen spectrum, which invariably decreased considerably during the first few seconds after the current was closed. This irregularity disappeared after a time, although the conditions were never so steady as in the experiments with hydrogen.

INFLUENCE OF MERCURY VAPOR.

Experiments were made first with pure nitrogen, afterwards with mixtures of nitrogen and mercury vapor in varying proportions. The vapor pressure of the latter was regulated by cooling the mercury reservoir connected with the tube. The intensities of the brightest red and orange bands of the nitrogen spectrum, and that of the green mercury line, were measured at different pressures of the nitrogen, and at different temperatures of the mercury reservoir. The intensity of the adjacent region of the nitrogen spectrum was deducted from the apparent intensity of the mercury line to get the time intensity of the latter. With time, the intensity of the mercury line gradually diminished during continuance of the current, and was renewed after a few seconds break of the current. Possibly this was due to a partial removal of mercury vapor by the combination of nitrogen and mercury, as described by Threlfall.[1] The measurements given below were therefore made immediately after the current was closed.

[1] THRELFALL, *Phil. Mag.* (5), 35, 1, 1893.

PURE *N*.

Pressure of *N*	Red Band	Orange Band	Green *N*	*Hg*
0.8	57	—	6	—
1.5	70	36	8	—
1.8	87	49	24	—
2.5	87	57	39	—
3.2	100	—	—	—
3.5	105	65	36	—
4	100	61	31	—
5	93	57	—	—
5.5	87	53	—	—
6	81	45	31	—
6.5	75	42	28	—
9	61	39	24	—
10	53	39	28	—
17	39	26	18	—
25	33	20	16	—
60	16	9	8	—
100	8	—	—	—
Temperature of *Hg* Reservoir — 4°.				
1.5	45	—	22	20
2.5	49	—	28	14
4	81	—	26	13
5	70	—	26	13
Temperature of *Hg* Reservoir + 5°.				
0.9	9	11	5	26
1.3	28	22	8	25
1.7	45	—	15	27
2.5	57	36	16	26
3	70	—	18	24
4	70	45	22	23
7	61	42	28	17
13	49	31	26	7
26	33	—	—	2
Temperature of *Hg* Reservoir + 17°.				
1.5	23	—	9	33
1.9	31	26	16	37
2.5	53	26	24	29
3.5	65	31	20	33
3.8	65	33	24	29
4	61	31	28	25
6.5	61	33	28	21
9.5	45	21	18	15
15	36	28 (?)	16	8
26	31	16	13	3

The results for the red band are represented in the curves (Fig. 1). These curves show a maximum intensity at a pressure of about 3.5 mm. Above a pressure of some 20 mm the intensity decreases very slowly with increasing pressure.

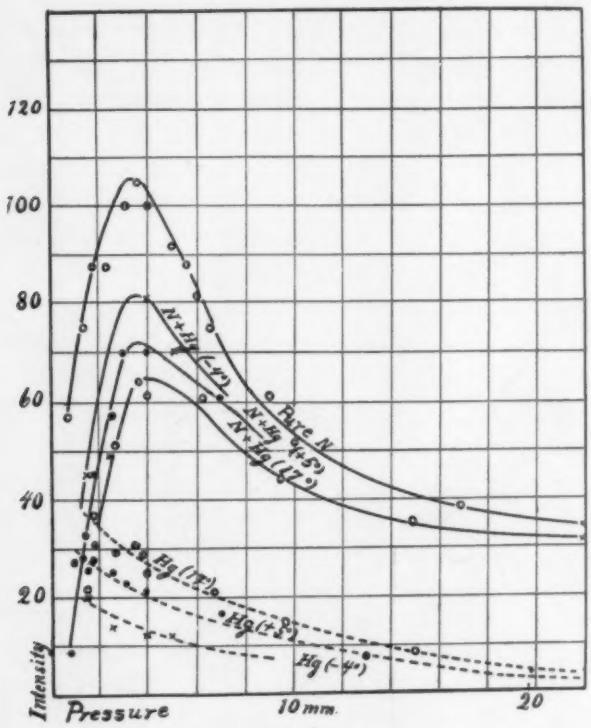


FIG. 1.

The intensity of these bands was considerably decreased by the presence of mercury vapor, although not so much so as in the case of hydrogen.

It is remarkable that the removal of mercury vapor from the tube, although followed by a diminution in the intensity of the green mercury line, was never followed by an increase in the intensity of the nitrogen spectrum. Such a result was invariably observed with hydrogen. Below is an example:

Pressure of *N*	Red	Orange	Green	*Hg*	
4 mm	107	42	33	0	No *Hg*
	45	28	18	52	*Hg* at 20°
	45	28	11	13	*Hg* at — 5°

INFLUENCE OF OXYGEN.

Oxygen was generated by heating potassium permanganate in a bulb, from which small quantities could be admitted into the vacuum tube. Measurements were made on pure nitrogen, or nitrogen containing 1 or 2 per cent. of oxygen, and nitrogen containing traces of oxygen; also on air and nitrogen containing 5 and 50 per cent. of air. These two series of experiments were made under different conditions with respect to current strength, etc.; therefore the results are not comparable.

The intensity of the brightest orange band was measured.

1. Pure *N*		2. *N* + traces of *O*		3. *N* + 1 or 2 per cent. *O*	
Pressure	Intensity	Pressure	Intensity	Pressure	Intensity
0.9	41	0.9	34	1.2	6
1.5	60	1.5	36	2.3	6.4
3	68	2.5	43	2.5	6.4
4	62	3.5	59	3	6
5	50	5	47	5	4.8
6.2	36	—	—	8	2
12	18	—	—		
4. *N* + 5 per cent. air		5. *N* + 50 per cent. air		6. air	
1.5	45	1.5	26	1	8
3.5	49	3	28	2.8	15
5	49	3.7	31	3.5	18
10	33	4.5	24	5.5	15
20	20	10	18	8	9

The results for oxygen are shown in Fig. 2. The curves for air are similar.

INFLUENCE OF WATER VAPOR.

The mercury reservoir was replaced by a bulb containing a very concentrated solution of sulphuric acid. After measurements of the intensity of the spectrum of pure nitrogen had been made,

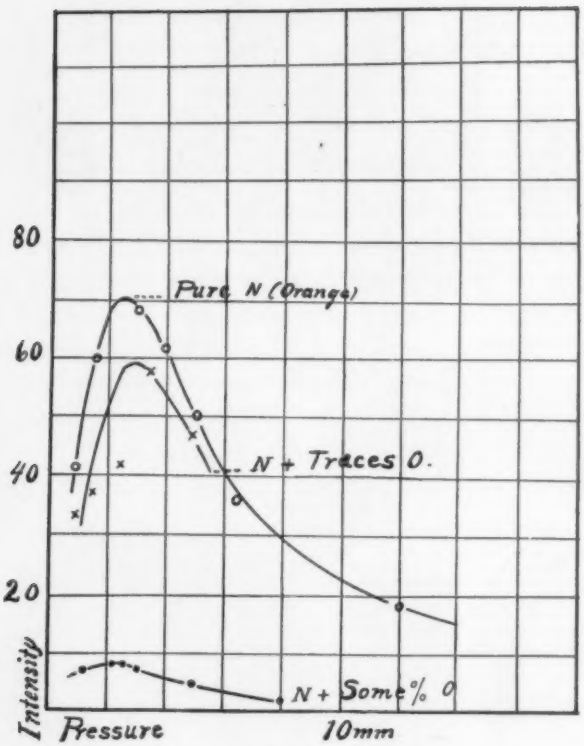


FIG. 2.

the cock between the bulb and the vacuum tube was opened. A considerable decrease (some 40 per cent.) in intensity was immediately observed. The results are given below.

1. Dry N			2. N + traces of H_2O		
Pressure	Red band	Orange band	Pressure	Red band	Orange band
1.3	70	33	1.5	28	18
2	87	45	2.5	45	24
3	100	53	2.9	53	26
3.5	93	53	3.2	57	31
4.5	81	45	4	57	31
7.5	70	42	4.5	53	28
10.5	57	33	7.5	45	22
24	36	18	12	24	20

After further dilution of the acid, the effect was considerably greater.

Pressure	Red	Orange	
4	93	53	Dry N
	7	3	$N+H_2O$

The red, yellow, and green parts of the spectrum were almost destroyed in the presence of considerable traces of water vapor, while the blue and violet bands remained plainly visible. In pure dry nitrogen the discharge was light pink at low pressures, copper red at higher pressures. After addition of oxygen, the color became violet.

INFLUENCE OF SULPHUR AND IODINE VAPORS.

These substances were respectively sealed in the discharge tube and heated. No change in intensity of the nitrogen spectrum was apparently caused thereby.

BERLIN PHYSICAL INSTITUTE,
March 1900.

PROMINENCES OBSERVED AT KALOCSA ON MAY 28, 1900.

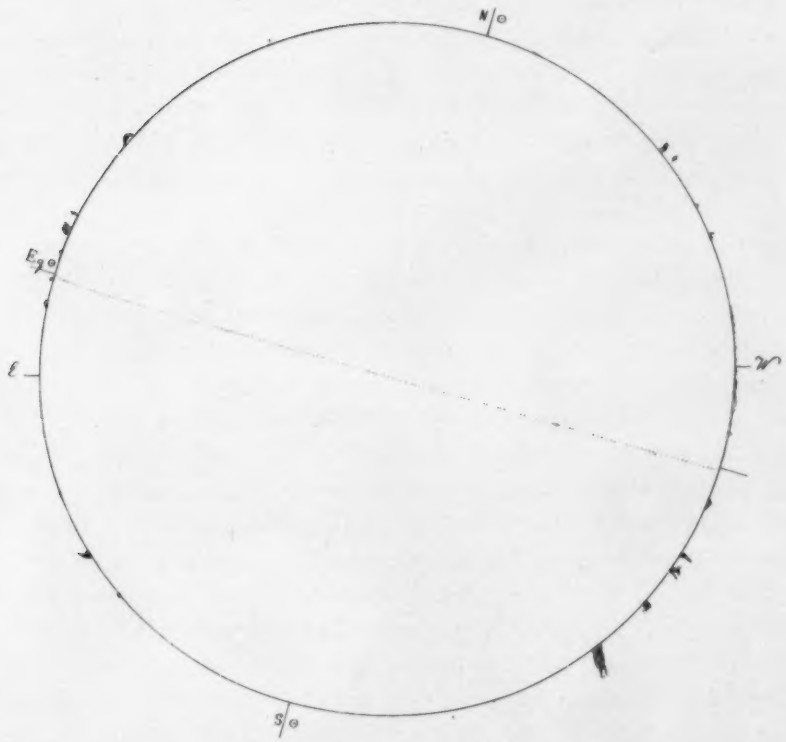
By J. FÉNYI, S.J.

AN automatic spectroscope of six prisms was employed for the observations. The atmosphere was unfavorable, but it was nevertheless possible to secure a complete observation of the Sun's edge at the time when the eclipse was total in North America. The measurements are included in the following table, and the drawing (Plate II) represents the forms sketched at the eyepiece. The height of 102″ is unusual for the present epoch of minimum.

Gr. M. T. civil	Position from N through E	Heliographic latitude		Height	Remarks
		E	W		
$12^h\ 0^m$	49°	+24°		24″	
12 52	307° 42′–308 22′		+55°	37	Changing rapidly
	306 46		+53	37	
	236 50 –237 36		—16	41	
1 17	233 50 –234 30		—19	33	Connected with last by light cloud
" "	226 56 –227 38		—26	28	
1 18	215 32 –217 24		—37	102	
1 24	119 30 –120 46	—47		32	Runs out into a very fine point
" "	64 22 – 65 46	+ 8		30	
1 30	63	+10		30	

Other smaller formations were observed in the positions 21°, 16°, 12°, 297°, 292°, 259°, 248°; from 265° to 280° the chromospheric flames were all inclined toward the equator.

PLATE II



PROMINENCES OBSERVED AT KALOCSA ON MAY 28, 1900

A SUGGESTED EXPLANATION OF THE SOLAR CORONA.

By J. SCHEINER.

IN addition to several bright lines the corona shows in the spectroscope a pretty intense continuous spectrum, in which the dark Fraunhofer lines have not yet been certainly detected and hence must be very weak. It follows from this that the corona can be due only in the slightest degree to reflected sunlight, and must be chiefly caused by the incandescence of solid or liquid particles.

The opinion seems hitherto to have been quite general that this incandescence arises in a manner similar to that of shooting-stars and meteors, from friction in the outer solar atmosphere which may be considered as constituted by the gases of the corona. This explanation does not seem to me to be valid, however, in view of the undoubtedly exceedingly slight density of the outer solar atmosphere. For how could such small particles come to incandescence from friction in a gas whose density is insufficient to appreciably affect by its resistance the orbits of comets passing through it? Moreover the particles would very soon fall into the Sun on account of the checking of the velocity, if they were not already wholly dissipated. New particles would therefore have to be constantly coming into the neighborhood of the Sun, and to render this view plausible, calculations have been made of the number of meteors striking the Sun on the basis of the corresponding figures for the Earth. I have elsewhere[1] pointed out the incorrectness of this procedure, since it involves the assumption that the universe is as densely occupied by meteoric matter as our solar system, which is without doubt not the case. Of course only a vanishingly small portion of the minute particles scattered through space, which have come into the domain of the Sun's attraction, has actually fallen into the

[1] *Strahlung und Temperatur der Sonne*, p. 66.

Sun; by far the greater part is forced into closed orbits by the Sun, and hence, in the course of the exceedingly long intervals of time in question, a sort of shell of meteoric particles has formed about the Sun, which shell must be inestimably more dense than space. This density is indeed applicable for our Earth, but only that of space for the Sun. We are here entirely leaving out of account the fact that perhaps the greater part of the meteors does not come from space, but originally belonged to the solar system.

The idea that the cause of the incandescence of the meteoric particles in the neighborhood of the Sun is to be found in the direct solar radiation is so obvious that it is surprising that it has not hitherto been expressed in the literature of the subject—at least I have been unable to find anything of the sort. This is perhaps because a rigorous solution of the problem of numerically determining the temperature of a body near the Sun is impossible, even if we were oriented as to its chemical constitution. But by adopting certain simplifying premises it is nevertheless possible to make a determination of temperature which must at least be of the right order, and which will therefore settle the question whether solid or liquid particles at distances from the Sun within the extent of the corona can be brought to the temperature of incandescence as a result of the solar radiation alone.

The premises are as follows: (1) The body is very small so that it will reach a stationary condition in a very short time, and the temperature of the interior will not appreciably differ from that of the surface. This assumption is nearly fulfilled by meteoric particles. (2) The emissive and absorptive power is independent of the temperature. This condition is the more nearly fulfilled as the body more closely approaches the absolutely black body; and it is for such a body only, which does not occur in nature, that the temperature can be exactly determined. After the analogy of the determination of temperature in case of the Sun, this may be designated as the effective temperature.

If we denote by q the quantity of heat radiated by an element of surface of the Sun in a unit of time, and by ϕ the apparent semidiameter of the Sun, the integral of the radiation upon an element of area perpendicular to the line of sight will be

$$W = \pi q \sin^2 \phi .$$

Hence the quantities of radiation received at various distances from the Sun vary with the square of the sine of the Sun's apparent semidiameter. According to the most recent researches, the quantity of radiation received per minute on a square centimeter at the distance of the Earth is $W = 4.0$ gram-calories.[1] Here $\phi = 16'$. An element of surface at such a distance that the Sun's semidiameter would subtend an angle of $45°$ — or at a distance of something less than half the solar radius from the Sun's surface, therefore corresponding to about the limit of the average extension of the corona — would therefore receive 23083 times as much radiation, or 92332 gram-calories.

On the given assumptions the effective temperature of the surface element can be computed from this, since a stationary condition will ensue as soon as the quantity of heat received and absorbed in a unit of time equals that emitted.

From Stefan's law this will occur at the absolute temperature T as soon as

$$W = \sigma \cdot T^4 .$$

The constant σ has been repeatedly determined in recent years, most lately and probably most accurately by Kurlbaum,[2] who obtained $\sigma = 1.28 \times 10^{-12}$, with the second as the unit of time. Hence $T = 5890°$ for the above defined point at the edge of the corona; that is, an absolutely black unit of surface would assume this as a stationary temperature, in so far as it was perpendicular to the line to the Sun's center. If we substitute for the unit of surface a small sphere under otherwise unchanged physical conditions, the receiving surface will be one fourth as large as the radiating surface in comparison with the plane surface element, and for this the mean value per second will be

[1] *L. c.*, p. 36.

[2] *Wied. Ann.*, 65, 746, 1898.

$W = 385$ gram-calories. Hence we obtain 4160° for the effective temperature of a small absolutely black body.

In view of the high degree of certainty as to the numerical values of W and σ, this value must be regarded as quite reliable; but if we attempt to pass from this over to the true temperature we shall be at once confronted with the difficulties already indicated.

All variations of the physical constants will produce a diminution of the value of T, but they cannot be exactly computed, because on leaving the absolutely black body the dependence of the absorptive and emissive power upon the temperature, which has not yet been sufficiently investigated, enters into the problem. A temperature of 4000° is therefore to be designated as the upper limit. The lower limit is at present beyond any exact computation; possibly we should come somewhere near it if it were permissible to use data of radiation applicable to the Earth. But unfortunately Stefan's law cannot be applied to bodies of such complicated physical structure as planets surrounded by atmospheres. The following figures may, however, give us some idea of the matter.

At the distance of the Earth from the Sun the absolute temperature of the small absolutely black body would be stationary at 338°; but the mean stationary temperature of the Earth's surface is 288°, and it should be noted that Zenker's researches indicate that the stationary temperature of the Earth's surface without solar radiation lies at 200°, when there will be equilibrium between the outward radiation and the conduction from the Earth's interior, so that the effect of the solar radiation amounts to only 88°.

Should we desire to deduce from this the stationary temperature of the Earth's surface, at the edge of the corona, according to Stefan's law, after we had computed, in place of the constant σ, a constant s, not physically definable, to be 278×10^{-10}, we should get $T = 1530°$, which is decidedly smaller than the upper limit but nevertheless considerably above the temperature of incandescence. I would again

expressly state, however, that there is no physical justification for this computation.

From the above considerations there seems to me to be no occasion for seeking any other cause for the continuous spectrum of the corona than in the very simple explanation given above

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REMARKS ON THE CONSTRUCTION AND ADJUSTMENT OF SPECTROGRAPHS. II.[1]

By J. HARTMANN.

III. SIZE OF PRISMS NECESSARY.

THE most favorable kind of prisms having been determined above, it remains to decide upon the most suitable size of those for a given instrument. Although it appears almost a matter of course that the prisms should always be large enough to receive the whole of the beam coming from the collimator, I shall nevertheless show that a certain, if only slight, increase in the brightness of the spectrum can be attained with somewhat smaller prisms. It seems desirable to determine accurately the minimum size of prisms possible, since the difficulty of accurate figuring and of perfect equilibrium of temperature during the measures increases with the size of the prisms, as does their price, and particularly their weight, as well as that of the whole prism box.

If the prisms are attached in the usual way, with their triangular surfaces between two metallic plates, it is obvious that their height, *i. e.*, the length of the refracted edge, must be made a few millimeters greater than the diameter of the collimator objective, and thin sheets of some not too hard, poorly conducting material, such as ivory, asbestos paper, etc., should be placed between the prisms and the metal plates. In this way we may avoid the passage of the rays through parts of the glass which are less homogeneous than the rest of the prism, either on account of unequal pressure of the plates or on account of the effect on the temperature of contact with the metal.

The side S of a prism which can receive the whole of the light coming from a collimator objective of diameter $2r$ may be computed from the formula

$$S = \frac{2r}{\cos i},$$

[1] Translated from the *Zeitschrift für Instrumentenkunde*, Vol. XX, Nos. 1 and 2, 1900, to which acknowledgment is also due for illustrations reproduced in this article.

where i is the angle of incidence at the surface of the first prism. If we now withdraw the prism from the position $A\,B\,C$ (Fig. 3), in which it receives the whole beam in the direction of its base $A\,C$, to about the position $A'B'C'$, the light coming from the segment $E\,F\,G$ of the objective (shown in the figure as turned ninety degrees from its actual position) passes by the refracting edge B' unutilized, but all the remaining light now has to cover a shorter distance in the glass than before by the thickness of the glass plate between $B\,C$ and $B'C'$. In this way we obtain enough diminution of loss by absorption so that up to a certain limit an increase in the brightness of the spectrum is possible by means of thus withdrawing the prism. The prisms may then be reduced in size by the portion $A\,A'C'D$, and the size of the prism box and also of the camera objective are correspondingly decreased.

Let $I\,K$ be a chord of the circular aperture of the collimator parallel to the refracting edge, g be its distance from the center of the aperture, reckoned as positive toward the refracting edge, $h = I\,K$ its length, and 2α the corresponding angles at the center. Then

$$g = -r\cos\alpha\,, \quad \text{and } h = 2r\sin\alpha\,.$$

If a second chord is drawn at a distance of $g + dg$ from the center, the two chords will include an element of surface of the aperture of area

$$dv = h\,dg = 2r^2\sin^2\alpha\,d\alpha\,.$$

If the chord $E\,F$, which separates the rays entering the prism from those which pass by the refracting edge, is at a distance of g_0 from the center of the aperture, and has the angle $2\alpha_0$ at its center, we shall have, similarly,

$$g_0 = -r\cos\alpha_0\,.$$

The pencil passing through the element of surface dv strikes the prism at a distance of

$$k = (g_0 - g)\sec i$$

from the refracting edge, and has to traverse in the prism a path of length

$$w = 2k \sin \frac{b}{2} = 2 (g_0 - g) \sec i \sin \frac{b}{2} .$$

For m prisms the length of path in the glass is mw.

If for brevity we set

$$2mr \sec i \sin \frac{b}{2} = z ,$$

we get

$$mw = 2mr (\cos a - \cos a_0) \sec i \sin \frac{b}{2} = z (\cos a - \cos a_0) .$$

The coefficient of absorption of the glass being c, as before, the intensity of the light emerging from the prisms, after traversing the distance mw in the glass, is given by

$$J = J_0 c^{mw} = J_0 c^{z (\cos a - \cos a_0)} .$$

The light passing through the surface element dv accordingly becomes

$$dL = J_0 c^{mw} dv = 2r^2 J_0 c^{z (\cos a - \cos a_0)} \sin^2 a da ,$$

and the total quantity of light transmitted through the whole prism train is

$$L = 2r^2 J_0 \int_0^{a_0} c^{z (\cos a - \cos a_0)} \sin^2 a da .$$

Now the light emerging from the collimator objective is

$$L_0 = r^2 \pi J_0 ,$$

and consequently the weakening of the light by the prisms is

$$\frac{L}{L_0} = \frac{2}{\pi} \int_0^{a_0} c^{z (\cos a - \cos a_0)} \sin^2 a da .$$

Loss of light by reflection is disregarded in this whole discussion, since it is independent of the size of the glass surfaces.

The integration is rendered easily possible by development in series. If we further let $c = e^x$, whence $x = \log \text{nat } c$, we get

$$\frac{L}{L_0} = \frac{2}{\pi} e^{-xz \cos a_0} \int_0^{a_0} e^{xz \cos a} \sin^2 a da .$$

Now

$$\int e^{xz\cos\alpha}\sin^2\alpha\,d\alpha=\int(1-\cos^2\alpha)\left(1+\frac{xz\cos\alpha}{1!}+\frac{x^2z^2\cos^2\alpha}{2!}+\frac{x^3z^3\cos^3\alpha}{3!}+\ldots\right)d\alpha=\int\left\{1+xz\cos\alpha+\left(\frac{x^2z^2}{2!}-1\right)\cos^2\alpha+\left(\frac{x^3z^3}{3!}-\frac{xz}{1!}\right)\cos^3\alpha+\left(\frac{x^4z^4}{4!}-\frac{x^2z^2}{2!}\right)\cos^4\alpha\ldots.\right\}d\alpha\,.$$

Introducing the known values of the integrals of the cosine powers, we obtain the series

$$\int e^{xz\cos\alpha}\sin^2\alpha\,d\alpha=\frac{1}{2}p_0\alpha+\frac{2}{3}p_1\sin\alpha+q_1\sin\alpha\cos\alpha+q_2\sin\alpha\cos^2\alpha+q_3\sin\alpha\cos^3\alpha+\ldots.$$

where the coefficients p and q have the following values, the symbolic designation $(n)=\frac{x^nz^n}{n!}$ being employed:

$$p_0=1+\frac{1}{4}(2)+\frac{1}{6}\cdot\frac{3}{4}(4)+\frac{1}{8}\cdot\frac{3}{4}\cdot\frac{5}{6}(6)+\frac{1}{10}\cdot\frac{3}{4}\cdot\frac{5}{6}\cdot\frac{7}{8}(8)+\ldots..$$

$$p_1=\frac{1}{2}(1)+\frac{1}{5}(3)+\frac{1}{7}\cdot\frac{4}{5}(5)+\frac{1}{9}\cdot\frac{4}{5}\cdot\frac{6}{7}(7)+\frac{1}{11}\cdot\frac{4}{5}\cdot\frac{6}{7}\cdot\frac{8}{9}(9)+\ldots.$$

$$q_1=\frac{1}{2}p_0-1$$

$$q_2=\frac{1}{3}p_1-\frac{1}{2}(1)$$

$$q_3=\frac{1}{3}[2q_1+1-(2)]$$

$$q_4=\frac{1}{4}[3q_2+(1)-(3)]$$

$$q_5=\frac{1}{5}[4q_3+(2)-(4)]\,.$$

Since the above integral vanishes for $\alpha=0$, we obtain for the weakening of the light by the prism the expression

$$\frac{L}{L_0}=\frac{2}{\pi}e^{-xz\cos\alpha_0}\sin\alpha_0\left\{\frac{1}{2}p_0\frac{\alpha_0}{\sin\alpha_0}+\frac{2}{3}p_1+q_1\cos\alpha_0+q_2\cos^2\alpha_0+q_3\cos^3\alpha_0+\ldots.\right\}.$$

The constants of spectrograph III, which has been described above, are

$$2r = 32\text{mm}\,, \quad b = 63^\circ 28.'0\,, \quad i = 61^\circ 43.'5, \quad m = 3\,.$$

From this follows

$$\log z = 2.02772\,.$$

For the flint glass of these prisms

$$\log c = 9.9972428\,,$$

whence

$$x = -\,0.0063488$$

and

$$\log xz = 9.83042n\,.$$

For this spectrograph the expression for $\frac{L}{L_c}$ accordingly takes the form

$$\frac{L}{L_o} = 0.63662\, e^{0.67674\cos a_o} \sin a_o \left\{ 0.529175 \frac{a_o}{\sin a_o} - 0.232558 \right.$$
$$- 0.470825 \cos a_o + 0.22209 \cos^2 a_o - 0.05688 \cos^3 a_o + 0.01029 \cos^4 a_o$$
$$\left. - 0.00145 \cos^5 a_o + 0.00017 \cos^6 a_o - 0.00002 \cos^7 a_o \right\}.$$

The series converges so strongly as to offer no difficulties in calculation. Thus I obtained the following table:

a_o	$\frac{L}{L_o}$	Brightness of spectrum
180°	0.5379	1.0000
170	0.5424	1.0083
160	0.5514	1.0250
150	0.5591	1.0393
140	0.5603	1.0416
130	0.5512	1.0247
120	0.5290	0.9834
110	0.4926	0.9158
100	0.4425	0.8227

If the prism is withdrawn in the manner described there occurs, at first, a not inappreciable increase in the brightness of the spectrum, reaching 4 per cent. at 140°. In spectrograph III the prisms would have a length of face of 67.55 mm in order to receive all the light from the collimator, while the prisms with the greatest light power according to the above table have a

length of face of only 59.65 at 140°. A face of 60 mm was accordingly given to the first prism, that nearest to the collimator objective. In the second prism this was increased to 65 mm on account of the spreading of the beam from the dispersion, and in the third prism the length of face was 70 mm.

It is by no means intended in what has been said that use should be made in all cases of this reduction in the size of the prism, but it is solely desired to determine the limit permissible for such a reduction. It would be entirely incorrect to place a prism in the path of the rays in such a way that its smallest portion, in the neighborhood of the refracting edge, should be unused. On account of its intensity this part furnishes the most valuable contribution to the spectrum, and care must therefore be taken that the surfaces of the prisms are perfectly figured close up to the refracting edge.

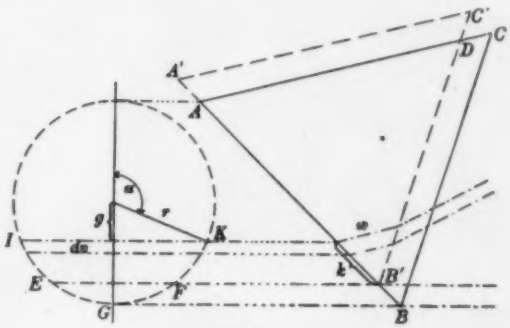


Fig. 3.

We may here mention an objection which might be offered to this reduction in the size of the prisms. It is well known that for the same kind of glass and the same refracting angle the resolving power of a prism is proportional to the length of face. This theorem, however, is rigorously true only for beams of rectangular section which fill out the whole prism; in the case before us, where the larger prisms have the single advantage that they could also include the light coming from the small segment EFG (Fig. 3), that proportionality does not occur. According to the researches of Rayleigh a circular beam of diameter $2r$ has in the spectroscope the same resolving power as a rectangular beam of width $1.8\,r$. Now, since in the suggested reduction of the prisms the section of the beam

approaches more nearly the rectangular form, the smaller prisms will be at least equally effective as the larger ones in respect to resolving power.

IV. TESTS AND ADJUSTMENT OF APPARATUS.

The first tests of the new spectrographs which I undertook dealt with their separate optical parts. The prisms were investigated with a large Bamberg spectrometer, and the lenses were tested on an optical bench.

The preliminary tests of the lenses had given the focal lengths for the different colors (particularly for $H\gamma$ light, by photographs of a hydrogen tube), and so the slit could be accurately placed in the photographic focus of the collimator. As the accurate focusing of the collimator is very important I will here describe the process I have employed for determining the focus for $H\gamma$.

The collimator objective to be investigated was placed upon an optical bench with a Geissler hydrogen tube set up several meters distant. The objective was covered with the diaphragm containing two slits parallel to each other, each of 2 mm width and 16 mm distant from each other. When the direction of these slits is parallel to the Geissler tube, two plane beams of light emerge from the objective, which intersect in a straight line which is the image of the tube projected by the lens. If we therefore receive the rays on a photographic plate we shall obtain a *single* image of the tube, that is a straight line, only in case the plate passes exactly through the intersection of the beams, or is precisely focused. But if the plate is not placed at exactly the right position, being at a greater or less distance from the objective, it will give two images of the tube, that is, two parallel straight lines, the separation of which, e, is proportional to the distance of the plate from the position of the image projected by the objective. If the displacement of the plate in the direction of the axis of the objective is measured on a scale which reads A for the correct setting on the image of the tube, and if we obtain two images on the plate separated from each

other by the distance e when the scale reading is A, we shall get the general relation

$$\frac{e}{A - A_0} = \text{const} .$$

If we make two exposures of this sort with different focusing, we shall obtain the relation

$$\frac{e_1}{A_1 - A_0} = \frac{e_2}{A_2 - A_0} ,$$

whence follow these two expressions for determining A_0:

$$A_0 = A_1 - e_1 \frac{A_1 - A_2}{e_1 - e_2} ,$$

$$A_0 = A_2 - e_2 \frac{A_1 - A_2}{e_1 - e_2} .$$

It will be of advantage to arrange the exposures so that the true position of the image is included between them, that is, so that $A_1 < A_0$ and $A_2 > A_0$; in which case e_1 must receive the minus and e_2 the plus sign. Where great accuracy is desirable several exposures at different settings of the plate will be made, instead of only two.

The procedure described is exceedingly reliable. In the ordinary method of focusing, in which we judge only by the *sharpness* of the image, the determination of focus is often uncertain by whole millimeters for lenses of small angular aperture, but a few extra-focal exposures, as above, will give the tenth of a millimeter with absolute certainty. I will give here a series of such exposures made with the collimator objective of spectrograph III, as an illustration. I obtained the following eight exposures on the same plate when the distance of the Geissler tube from the front edge of the cell of the objective was D = 3028.4 mm :

No.	A	e
1	189 mm	+ 2.053 mm
2	179	+ 1.779
3	169	+ 1.480
4	159	+ 1.197
5	109	− 0.244
6	99	− 0.536
7	89	− 0.822
8	79	− 1.112

On combining the exposures in pairs 1 and 5, 2 and 6, 3 and 7, 4 and 8, there result these eight values A_0:

$A_0 = 117.49$ mm
117.53
117.56
117.53
117.50
117.52
117.57
117.53

Mean, 117.53 mm.

The distance of the plate from the edge of the cell of the objective corresponding to the value $A=0$ is 458.78 mm, whence the distance of the image from that edge is $d=576.31$. The value of d was determined in this way for a number of different values of D, and thus the position of the focus for parallel rays, that is for $D=\infty$, was computed in the ordinary manner. In order to discover any change of focus with temperature, I made the measurements at two different temperatures, and obtained for the distance d of the focus from the edge mentioned

at 19°.2 C, $d_0 = 486.17$ mm
2.0 486.35

Although the difference of these two numbers lies near the limit of accurate determinations, in view of the accuracy of the method employed it may be considered trustworthy; whence would follow a shortening of the focus relative to brass of 0.1 mm for a change in temperature of 10° C. Since the distance of the slit of the collimator objective in spectrograph III is fixed once for all, the rays will emerge from the collimator exactly parallel only at a definite temperature t_0. At a temperature of $t_0-10°$ they emerge with a divergence equal to that from a slit at a distance of 2.3 km. It is clear that so slight a divergence of the rays has no effect on the sharpness of the spectrum if the small alteration of the path of the ray due to the temperature coefficient of the collimator is compensated by suitable focusing of the camera.

The following procedure may be adopted for obtaining a sharp image over the longest possible region of spectrum. If the collimator objective is achromatized in such a way that the point of inflection of the color curve falls at that wave-length for which the prisms are to be set at minimum deviation, we shall not place the slit exactly in the focus for this wave-length, as this has the shortest focus of any point in the whole spectrum, but we shall slightly increase the distance of the slit from the collimator objective. Then two sets of rays lying on either side in the spectrum will emerge from the collimator in exact parallelism, hence homocentrically, while the middle part of the spectrum will be also homocentrically represented for the reason that the prisms are set at the minimum of deviation for this point. It has been possible in case of the two spectrographs under discussion to secure sharp definition of a much longer extent of spectrum than with any previous stellar spectrographs. In apparatus I, which has one prism, the region between Fraunhofer lines D and N, corresponding to a difference of wave-length of $230\mu\mu$, is sharply defined; with spectrograph III, having three prisms, the region from *b* to K is depicted with perfect sharpness. It is of great importance, for stellar spectrographs in particular, to extend the region of sharply defined spectrum as far as possible, as we then obtain a considerably more extensive supply of observed data with the same exposure time as if a short portion only of the spectrum was well defined by the spectrograph.

After completing the further adjustment of the apparatus—the accurate perpendicularity of the edges of the prisms to the axes of collimator and camera, the setting of the prisms at the minimum of deviation for $H\gamma$, and the determination of the most suitable inclination of the plate-holder to the axis of the camera—an exhaustive testing of the completed spectrograph was undertaken.

The essential condition placed on the optical performance of a spectrograph is briefly that it shall unite in an absolutely sharp image of the slit on the photographic plate all the rays of the same wave-length which fall upon the collimator objective after

passing through the slit, neglecting the hardly appreciable diffraction phenomena which depend upon the aperture of the camera objective. This image is the "line" corresponding to that wave-length. The condition of sharp definition point by point, according to which a sharp point image on the plate corresponds to each separate point of the slit, is not absolutely essential, and in concave gratings this condition is not fulfilled. A good prism train, however, will satisfy this condition also. If a spectrograph conforms to the condition first named, it is at once evident that the position and the sharpness of the line cannot be at all affected by the question whether the ray has fallen perpendicularly or obliquely upon the slit, or whether the ray has been concentrated accurately on the slit by a lens or upon a point in front of or behind it. If any such alteration in the path of the rays produces displacement, broadening, or lack of sharpness of the line, then the above fundamental principle of the apparatus is not fulfilled, and such an instrument is not suitable for exact measurements. Conclusions as to the actual appearance of the lines in the spectrum, as to their sharpness, breadth, and diffuseness on one side, and similar matters, cannot be drawn until the observer has convinced himself that the cause of these phenomena cannot lie in the instrument employed.

Photographs of suitable spectra are obtained in the preliminary tests of the spectrograph. Direct sunlight is less to be recommended for this purpose; for if it is allowed to fall upon the slit, after reflection from the mirror of a heliostat, only a narrow beam of light will enter the collimator, if the slit is not very narrow, so that only small portions of the prisms and objectives are employed, while the remaining parts contribute nothing to the production of the image. Even if the solar spectrum photographed in this way is perfectly sharp, it proves nothing as to the excellence of the instrument. The most important rule in all test plates is always to uniformly illuminate the *whole* collimator objective. This can be accomplished in case of sunlight by the use of a projecting lens, or much more simply and certainly by placing a ground glass disk at a slight distance in front of the

slit. Diffuse light of the sky may also be used for test plates. If a solar spectrum obtained in this way appears perfectly sharp it may be assumed that the spectrograph has no large errors, but such a test is not entirely certain, as the numerous lines and weak contrasts of the solar spectrum easily allow a slight lack of sharpness in the lines to escape attention.

The line spectra of metals and of gases in Geissler tubes are decidedly better adapted for testing the apparatus. Any one having an electric arc lamp at his disposal can form an accurate opinion as to the quality of the spectrograph in a few minutes. The lamp should be placed some 50 cm in front of the slit and a ground glass disk inserted between the lamp and the slit. One may be quite certain that the apparatus is excellent, if on vaporizing a metal, as iron, in the arc, the lines remain absolutely sharp with strong illumination, particularly if they are not diffuse on one side. In default of an arc lamp the spark spectrum of metals can be employed, but much longer exposures will be necessary on account of its weaker luminosity. The desired result will be obtained more rapidly in this case if a projecting lens is substituted for the ground glass disk for giving full illumination to the collimator objective. To secure certainty that the lens correctly performs its purpose the eye should be placed in the position of the image of some readily visible lines, the plate-holder having been removed from the camera. For this purpose the bright lines of the air spectrum in the yellowish-green, which always occur in spark spectra, are suitable. On looking toward the camera objective the *whole* collimator objective should be seen as uniformly luminous in the proper color through it and the prisms. Geissler tubes giving strong line spectra, as hydrogen tubes, are also very useful. The capillary part of the tube should be placed parallel to the slit and as close to it as possible, attention being given that the slit is narrower than the luminous capillary and receives light uniformly over its whole width. This may be recognized by the fact that the edges of the slit only, and not a part of the tube, are perceived as boundaries of the lines when examined with an eyepiece put in the

position of the plate-holder and sharply focused on the lines. If the eyepiece is then removed, the *whole* of the collimator objective must again be uniformly luminous in the proper color. In these tests longer exposures should be always employed along with the shorter ones, and one should convince himself whether the lines remain perfectly sharp in all cases.

In the investigation of the two spectrographs often alluded to, I have employed another method, which is indeed much more troublesome, but furnishes an absolutely certain criterion as to the trustworthiness of the apparatus. It will always be necessary to fall back upon this method if the lines have lacked sharpness in the above-mentioned tests, and the cause is to be further investigated.

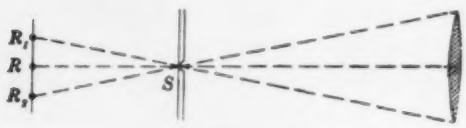


Fig. 4.

A hydrogen tube R was mounted parallel to the slit S at a distance of about 25 cm from it (see Fig. 4) in such a way that it could be moved micrometrically in a direction perpendicular to the axis of the collimator. For this purpose I mounted it on the slide of a dividing engine. A narrow, plane beam of light will enter the collimator if the slit is not too narrow (say, from 0.05 mm to 0.1 mm). In one position of the tube R_1, this beam will fall upon one edge of the collimator objective, and at another position R_2, upon the opposite edge of the collimator objective. The light from the tube will pass from the point R, lying between R_1 and R_2, accurately through the axis of the collimator and through the center of the prisms and the camera objective. Let the whole distance R_1 R_2 be divided into a number of equal divisions so that the light may be successively thrown from the different points upon all points of the collimator objective. Let the tube be now set on one of the divisions, the middle of the slit be covered by a small strip, and a spectrum be photographed. After interrupting the current the tube is moved into the position R, the middle of the slit is opened and the lateral portions are closed, and a second exposure is made on

the same plate, the plate-holder having of course remained untouched meanwhile. In this way two spectra are obtained on the plate one above the other, the inner of which has been produced by the central portion of the spectrograph, while the exterior spectrum lying on both sides is due to light which has passed through the outside parts of the objectives and of the prisms. If the exterior spectrum then shows no displacements of the line with respect to the interior one, it follows that the central and the lateral beams intersect precisely in the plane of the plate. But if the two spectra are displaced with respect to each other it will always be possible to cause this displacement to disappear by focusing the plate. This problem may be seen to be entirely identical with the method of focusing explained above. Having accomplished the result that the central ray intersects a lateral ray exactly in the plane of the plate, the spectra of all the separate lateral rays should then be successively photographed at the same focus, the Geissler tube being set at the different divisions of the space R_1 R_2. For comparison the spectrum produced by the axial rays from R should be introduced in every spectrum. If all of the spectra thus obtained are then tested under the microscope, and if no one of them exhibits a displacement from the central spectrum, then the condition proposed above is rigidly fulfilled, the spectroscope is free from aberrations, and the position and sharpness of the lines is independent of the direction from which the rays fall upon the slit.

Two cases may arise if a perfect coincidence with the central spectrum has not occurred for all the lateral spectra. Either a uniform progress will show itself in the displacement, so that the spectrum produced, say from R_1, is displaced most strongly in the direction of shorter wave-lengths, and that from R_2, on the contrary, in the direction of longer wave-lengths as compared with the central spectrum. This would prove that the plate was not correctly focused as it should have been, and a progressive change of this sort can always be overcome by changing the position of the plate. But if the two spectra from R_1 and R_2 are displaced in the *same* direction with respect to the central

spectrum, the apparatus is without question imperfect and can only be employed by stopping out a part of the prism. The following figures, which I have found in investigating spectrograph I, which has only *one* prism, may serve as an illustration of this. The measurement of seven spectra obtained in the manner described yielded the following displacements with respect to the central spectrum:

Point	Displacement
1 (R_1)	+0.040 mm
2	+0.014
3	0.000
4 (R)	0.000
5	+0.003
6	+0.020
7 (R_2)	+0.050

Since all the displacements have the same sign, all lying in the direction of shorter wave-lengths, there will be no focus at which all the rays can be united in a sharp image on the plate. If we are willing to permit a lack of sharpness of 0.1 mm, the lateral portions of the prisms from 1 to about 2.3 and from 5.5 to 7 will have to be covered. As a third of all the light would be lost in this process, however, a new prism was obtained for the spectrograph, which on renewed investigation showed itself to be entirely free from error.

If the lines of the separate lateral spectra should appear diffuse instead of sharp on the plates, the prism or perhaps one of the objectives is imperfect in the direction of the refracting edge. The path of the rays in this direction must then be separated into sections by diaphragms placed over the collimator objective, and each must be investigated for itself. For the investigation described above, such diaphragms can also be employed, their aperture consisting of a slot parallel to the refracting edge;[1] but the danger arises of putting an injurious pressure on the parts of the apparatus in changing the diaphragms, which might affect the accurate coincidence of the

[1] Cornu suggested the employment of a diaphragm with circular aperture of about 5 mm diameter (*Spectre normal du Soleil*, p. 10).

spectra. This danger is avoided by the use of the movable Geissler tube.

I have been able to prove in the way described that all the rays which pass in any way through the optical parts of spectrographs I and III are perfectly united in a sharp image of the slit. As may be seen from what precedes, such a union of the rays on the plate is only possible when the latter is perfectly focused, and all spectral plates therefore require an extremely careful focusing. The means hitherto employed of concluding as to the correct position of the plate solely from the sharpness of the lines of the spectrum appear to me to be insufficient, and an attachment has therefore been applied to the two instruments which permits the use of the method of focusing by extra-focal exposures described above. The arrangement consists in placing two diaphragms successively in front of the objective of the collimator, with which we first allow the light to fall only upon the portion of the prisms near the refracting edge, and then only upon the portion near the base of the prisms, the light meanwhile being prevented from falling upon the opened plate-holder. The plate being out of the correct focus, the two spectra obtained through the diaphragms are placed in juxtaposition by covering up part of the slit.[1] The correct focus is then obtained as described with the greatest precision from the displacement of the two spectra. The two apertures may be made in one and the same diaphragm, but in that case the observer is restricted to the employment of spectra with few lines, such as that of hydrogen, while when separate diaphragms are employed the focusing can be effected with daylight.

I must not omit to mention that the method of focusing here described is only permissible after the optical parts have been investigated as above and found satisfactory, for it is only in this

[1] NEWALL also suggested (*M. N.*, 57, 572, 1897) a similar method of employing diaphragms in focusing, but in finding the focus he availed himself only of the fact that at that point the images from the two apertures in the diaphragms coincided. Similar methods have been known for a long time: H. Schroeder gives a very useful procedure in his *Photographische Optik*, p. 171. The advantage of the method of extra-focal exposures that I have employed consists in the fact that a reliable linear measurement is substituted for the always uncertain estimate of the sharpness or coincidence of lines.

case that we are justified in regarding the point of intersection of the two emerging beams from the objective as the focus of the rays coming from the *whole* objective.

This method of extra-focal exposures has also proved to be of especial utility in testing and in exactly determining the focus of telescope objectives at this Observatory. I will here only briefly mention the following point: With the use of suitable diaphragms the extra-focal exposures will furnish the focal length of all the separate portions of the objective, and hence accurate numerical data as to the course of the zonal errors and of the astigmatism. If the extra-focal images are received upon the slit of a spectrograph, and not directly on the photographic plate, the color curve of the objective may be obtained at the same time. The results of researches of this sort carried out here on larger objectives will be published in detail elsewhere.

V. A DIAPHRAGM FOR THE SLIT OF THE STELLAR SPECTROGRAPH.

In photographing stellar spectra for the determination of motion in the line of sight it is necessary to place the spectrum of a terrestrial source beside that of a star, and for the sake of accuracy in measurements, the comparison spectrum is placed as near as possible above and below the star spectrum. The following device was attached to spectrograph III for accurately placing the spectra in juxtaposition, and it has proved very useful in the work that has been done in the laboratory.

A slide of sheet brass, which can be moved back and forth something more than 2 cm in the direction perpendicular to the slit, is attached just in front of the slit. This slide contains an aperture of the form shown in Fig. 5. The central part of the aperture is a rectangle $ABCD$, somewhat greater than the height of the slit and wide enough so that the slit can be reached for cleaning. An isosceles triangle EFG joins the aperture at the left and makes it possible to give any desired breadth from about 3 mm down to less than 0.1 mm to a spectrum produced at the middle of the slit. A rectangle $HIKL$ connects with the side BC on the right, and into this projects the tongue MNO similar to the triangle EFG. A portion of the middle of the slit up to

3 mm length can be covered by this tongue, while the slit remains free for receiving the comparison spectrum above and below it. In the measurement of the spectra it is convenient to have the comparison spectra only a few tenths of a millimeter broad, similar to the star spectrum, and not of indefinite breadth. For effecting this, a second and smaller slide (Fig. 6) was attached to the first, containing only a triangular aperture PQR, as nearly as possible like the tongue MNO, by which it is partially covered in use as may be seen from Fig. 6. The upper slide may be moved a few millimeters on the lower one in the direction perpendicular to the slit, and is held in position by friction with the

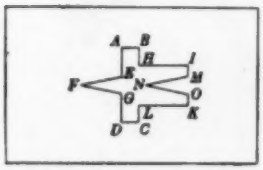


Fig. 5.

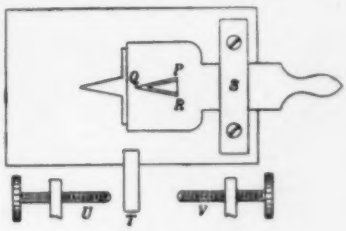


Fig. 6.

clip S. The comparison spectra will have a greater or less breadth as the upper slide is placed more or less toward the left upon the lower slide.

The motion of the whole diaphragm is limited by the adjustable stops U and V, against which the projection T, which also serves as a handle, strikes. These stops make it possible to always bring exactly the same parts of the diaphragm in front of the slit, so that the same breadth can be given to all the spectra on a series of plates. This diaphragm is capable of very numerous applications. Spectra may be taken with a width of 15 mm (AD), 8 mm (HL), and 3 mm down to less than 0.1 mm (EFG). Two comparison spectra of any desired width can be then placed beside the last named spectra, of less than 3 mm width, either in direct contact or symmetrically separated by a space. It is easy with this device to place three spectra in exact juxtaposition in a space one half a millimeter wide.

ASTROPHYSICAL OBSERVATORY,
Potsdam.

NOTE ON THE SPECTRUM OF SILICON.

By FRANZ EXNER and EDUARD HASCHEK.

IN an article "On the Origin of Certain Unknown Lines in the Spectra of the Stars of the *β Crucis* Type and on the Spectrum of Silicon," by Mr. Joseph Lunt, which appeared in No. 4, Vol. XI, of this JOURNAL, attention was called to Dr. Gill's recognition in the spectra of several stars of lines of the wave-lengths 4552.79, 4567.09, and 4574.68, the identity of which had not previously been determined. McClean had observed the same lines in the spectrum of *β Crucis*, assigning them wave-lengths 4552.6, 4567.5, and 4574.5. Sir Norman Lockyer had also recorded these lines as unknown. Mr. Joseph Lunt has, however, made a series of experiments which show with a high degree of probability that these lines belong to the spectrum of silicon, and has expressed his regret that the measurements accessible to him, those of Hartley and Adeney, as well as those of Eder and Valenta, do not include this special region of the spectrum, and so do not permit a direct confirmation of his view concerning the origin of the lines in question.

As we undertook some time since[1] the measurement of lines in the spectrum of the spark between electrodes of metallic silicon, with the aid of a large Rowland concave grating, and as the data from our table of wave-lengths completely confirm the opinion of Mr. Lunt as to the origin of the lines in question, we believe the communication of these results in the following table, so far as we have made measurements in the region of the Sun's spectrum, will not be regarded as superfluous.

[1] *Sitzungsberichte der Wiener Akademie*, Bd. 108, 1899.

SILICON.

λ	*i*	λ	*i*
2987.77	1	3905.71	5
3086.6	1[1]	4021.0	1[1]
3093.6	1[1]	4030.1	2[1]
3591.0	1[2]	4096.8	1[1]
3791.8	1[1]	4103.2	1[2]
3796.50	2[2]	4103.7	1[2]
3806.90	3[2]	4128.1	5[1]
3853.62	1[2]	4131.0	6[1]
3854.02	1[2]	4552.75	3[2,3]
3856.19	5[2]	4567.95	1[2]
3862.80	4[2]	4574.9	1[2]
3883.46	1	4764.20	1

In the recorded intensities *i*, 1 stands for the weakest lines.

From this table it appears that the lines observed by Dr. Gill and by McClean undoubtedly belong to the spectrum of silicon. The pronounced discrepancy in the wave-length of the line 4567.09 may arise through an error. The two lines 3834.4 and 3826.7 attributed to silicon by Eder and Valenta, the existence of which in the spectrum of silicon was doubted by Mr. Lunt and which are lacking in our table, are iron lines. The line 3807, which Mr. Lunt suspected was a silicon line, although lacking in the silicon lines recorded by Eder and Valenta, appears in our table at 3806.90. In view of the above agreement it can scarcely be doubted that the opinion of Mr. Lunt was correct. The fact that the silicon appears in the spectra of so large a number of stars seems to us to be of especial interest because in our experience in this part of the spectrum we have found it very difficult to establish the presence of silicon as an impurity.

VIENNA, May 13, 1900.

[1] Very diffuse. [2] Diffuse. [3] The neighboring air line is 4552.65.

PRESSURE IN THE SPARK.

By EDUARD HASCHEK and HEINRICH MACHE.

IN Vol. X, No. 3 of the ASTROPHYSICAL JOURNAL Dr. J. F. Mohler computed the pressure of the electric spark from observations on the displacement of spectral lines. These measurements he undertook in the belief that the considerable pressures in the electric spark observed by the present writers would necessitate a marked displacement of the spectral lines. From the fact that under the experimental conditions of his investigation the observed displacement of the lines was relatively small he concluded that the pressures found by us were too high. Dr. Mohler found further that the influence of the surrounding gas upon the pressure of the spark affirmed by the present writers did not exist. In reply we wish to call attention to the following considerations.

Our statements concerning the pressure in the spark were accompanied by a detailed description of the apparatus and the conditions of experimentation. By comparing the values obtained with the transformer and those obtained with the Ruhmkorf coil the great influence of the apparatus used upon the results is apparent. The reason for this difference can in the opinion of the writers be sought only in the difference in the quantity of energy represented in single sparks in the two cases. That it depends upon this consideration is apparent from the interdependence between the capacity applied and the observed pressure, which was confirmed by Dr. Mohler also. This difference is especially noticeable when the energy of the spark is changed to the extent involved in passing from the transformer to an induction coil. In our experiments with the transformer an alternating current of from 6 to 9.5 amperes and 100 volts was driven through the primary. In the induction coil, on the contrary, a steady current of about 10 amperes and 12 volts

was used. The difference in energy consumption was thus very considerable, as was also the observed spark pressure. Thus Dr. Mohler, working with an induction coil, obtained values which agree with ours obtained in a similar way, at least so far as the strong influence exercised by the materials of the electrodes admits of a comparison between his results and our own. Further, in the statements of Dr. Mohler concerning the influence of the surrounding gas the present writers are able to see only a confirmation of their own results. We of course do not maintain, however, that numbers which differ by 45 per cent. are equal. That the pressure is higher in illuminating gas than in air may be due to the fact, as maintained by Dr. Mohler and which seems obvious to us also, that carbon may have been deposited from the gas upon the electrodes and that the present writers measured, not the pressure for brass, but for carbon. For carbon the observed spark pressure is indeed materially higher, and blackened electrodes give larger values than bright ones. Now for carbon dioxide, with which Dr. Mohler repeated the experiment, it is possible that like conditions entered. Dr. Mohler finds the relation between the pressure in carbon dioxide and air to be 1.45, while the ratio found by the present writers was 3. If one considers the quantitative difference in the energy consumption in both cases, it is easy to conclude that here also carbon was separated and deposited upon the electrodes, and indeed in greater quantities in using the transformer than in the case of the induction coil, whereby the observed discrepancy may be explained.

Minor Contributions and Notes

A NEW STAR IN *AQUILA*.

From an examination of the Draper Memorial photographs, Mrs. Fleming has discovered a new star in the constellation *Aquila*. Its position for 1900 is R. A. $= 19^h\ 15^m\ 16^s$; Dec. $= -0°\ 19'.2$. It was too faint to be photographed on 96 plates taken between August 21, 1886, and November 1, 1898, although stars as faint as the thirteenth magnitude are visible on some of them. It appears on 18 photographs taken between April 21, 1899, and October 27, 1899. On April 21 it was of the seventh magnitude, and on October 27, 1899, of the tenth magnitude. Two photographs taken on July 7, and July 9, 1900, show that the star is still visible, and that its photographic magnitude is about 11.5. A photograph taken on July 3, 1899, shows that its spectrum resembled those of other new stars, while a photograph taken on October 27, 1899, shows that the spectrum resembled those of gaseous nebulæ.

On July 9, 1900, the object was observed with the 15-inch equatorial by Professor Wendell, who estimated its magnitude at 11.5 to 12.0, and confirmed the monochromatic character of its spectrum.

E. C. Pickering.

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICACO.

BULLETIN NO. 13.

VARIABLE STAR OBSERVATIONS WITH THE 12-INCH AND 40-INCH REFRACTORS.

The principal observations of variable stars hitherto made at the Yerkes Observatory were included in Professor Barnard's study of star clusters with the 40-inch telescope. In connection with his extensive triangulations of certain clusters, he has observed the variations in brightness of a number of variable stars discovered photographically at the Arequipa station of the Harvard College Observatory. Professor Barnard has also made miscellaneous observations of variable

stars in the course of his general micrometrical work with this instrument.

During the summer of 1898 Mr. J. A. Parkhurst, whose private observatory is at Marengo, Illinois, was given the use of the 12-inch refractor on certain nights of each week for variable star observations.

The work with the 12-inch has recently been supplemented by observations with the 40-inch refractor, whose great light-gathering power has made it possible to follow a number of variables through very faint minima. This preliminary report will be followed by more definitive results when the magnitudes of the comparison stars have been determined with the stellar photometer, now in use in this work. The magnitudes given in the present paper are only approximate, based on the assumption that the limit of the 12-inch is 14.0 magnitude, and that of the 40-inch 17.0 magnitude.

Of the 22 stars in this report, 16 are contained in Chandler's *Third Catalogue of Variable Stars* and supplements. For these stars Table I gives from this catalogue the minimum magnitude and number of minima on record, to show what was previously known on the subject; also the results of the work at the Yerkes Observatory from January to June 1900, giving the date and magnitude of the observed minima.

TABLE I.

	From III. Cat.		Yerkes observations	
	Min. mag.	No.	1900	Min. mag.
267 *V Andromedae*	——	—	January	14
2530 *V Canis minoris*	<13.7	—	April	15
2625 *V Geminorum*	12.0–14.0	3		
2815 *U Geminorum*	13.1	—		
2976 *V Cancri*	<12	3	February	12
4315 *R Comae*	<13.5	—	March	<14
5070 *Z Virginis*	<14	—	May	15
5430 *T Librae*	<14.7	3	Feb. or Mar.	<16
5593 *W Librae*	<14	—		
5830 *R Scorpii*	<13	—	May	16
5831 *S Scorpii*	<13	—		
6100 *RV Herculis*	——	—	February	<15
6871 *V Lyrae*	<12	—		
6894 *S Lyrae*	12.0	—	May	16
7458 *V Delphini*	12?	—		

Six of the stars in Table I did not pass minimum during the time covered by this report; the following notes show the observed magnitudes, the stars being referred to by their numbers only:

2625 14.5 magnitude by the end of January, brighter by middle of February.

2815 Carefully followed throughout its period. About 14 magnitude at normal light, but with considerable fluctuations.

2976 Has a 13 magnitude companion, 10".8 preceding, on the parallel.

5593 15 magnitude and rising early in February.

5831 Apparently stationary at 15 magnitude in February.

6871 About 15.5 magnitude early in June and still fading.

7458 Maximum 1899 October 1, at 7.5 magnitude; invisible in 40-inch (low power) 1900 July 20, therefore < 17 magnitude: a range of nearly or quite 10 magnitudes.

TABLE II.

STARS NOT IN CHANDLER'S THIRD CATALOGUE.

	1900		Discoverer	*Ast. Nach.*	
	R. A.	Dec.		Vol.	Page
(1922)	$5^h\ 20^m\ 8^s.6$	$+36°\ 48'\ 53''$	Ceraski	148	15
(4696)	13 2 39 .5	−12 37 50	Schwassmann	152	183
(6458)	17 56 17 .2	+54 52 45	Anderson	151	307
(7258)	20 11 32 .9	+30 46 3	Anderson	150	325
(7579)	21 3 38 .5	+82 39 50	Ceraski	147	142
(8517)	23 39 41 .1	+56 1 35	Anderson	148	79

Particular attention has been paid to new variables, not in the Third Catalogue, whose light-curves suggest very faint minima. Table II gives six stars selected from these, showing the number (in parenthesis, provisionally assigned by Mr. Parkhurst), the place for 1900, found by micrometer measures with the 40-inch, except for the 2d and 5th, the discoverer, and a reference to the announcement of discovery in the *Astronomische Nachrichten*.

The preliminary results of the observations of these new variables are given in the following notes:

(1922) Minimum early in March, about 15 magnitude.

(4696) Not visible in the 12-inch June 20, limit about 13 magnitude. Between 13 and 14 magnitude July 5, with 40-inch.

(6458) Not visible in 12-inch in March, limit 14 magnitude; had risen to 10 magnitude by June 23.

(7258) Minimum in May, about 14.5 magnitude.

(7579) Had passed below the limit of the 40-inch in June, and therefore not brighter than 17 magnitude.

(8517) Stationary at about 15 magnitude in January, rising in February.

GEORGE E. HALE.

July 6, 1900.

POSITIONS OF *EROS* (433) IN 1893, 1894, AND 1896.[1]

APPROXIMATE positions of *Eros* (433) during the oppositions of 1894 and 1896 will be found in *Circulars* Nos. 36 and 37. Since then the photographs from which these positions were derived have been measured by the method described in the Harvard *Annals*, Vol. XXVI, p. 237, and reduced by the method of Turner. The measurements have been made by Miss E. F. Leland and the reductions by Miss A. Winlock aided by Miss I. E. Woods. These photographs were taken with the Bruce, Bache, and Draper photographic doublets, whose apertures are 60, 20, and 20 cm, and the focal lengths such that 1 mm equals 60″, 179″, and 163″, respectively. Photographs taken with these instruments are designated by the letters A, B, and I, respectively. The smaller instruments photograph a field 10° square, and as some of the images fall near the corners of the plate it was not supposed that positions could be determined from them with a high degree of accuracy. In some cases the images are more than 5° from the center of the plates, and are consequently much distorted, the greatest diameter exceeding a minute of arc; yet, as will be seen below, the accuracy of the places does not greatly differ from that ordinarily obtained with meridian circles. The most remarkable conclusion to be derived from these observations is that if, in the future, any other object like *Eros* should be discovered, we have at this Observatory the means of tracing its path since 1890, during the time in which it was moderately bright, with nearly as great accuracy as if a series of observations had been taken of it with a meridian circle.

In the following table the designation of the original negative is given in the first column. The date, the Greenwich Mean Time of the middle of the exposure, and the duration of the exposure, are given in the next three columns. Two enlargements, on a scale of 0.1 cm. = 10″, were made from each of these negatives, and their designations are given in the fifth column. The number of catalogue stars on these enlargements used to determine the constants of the plates, such as errors of scale, orientation, etc., is given in the sixth column. The standard coördinates of *Eros* are given in the seventh and eighth columns, and the resulting right ascension and declination for 1875 in the ninth and tenth columns. The two measures of each plate are independent, except for errors in the original negatives and in the

[1] *Harvard College Observatory Circular* No. 51.

POSITIONS OF *EROS*.

Plate	Date	G. M. T.	Exp.	Enl.	St.	X	Y	R. A. 1875	Dec. 1875	Δ R. A.	Δ D.
	y m d	h m	m			"	"	h m s	° ′ ″	s	″
I 9801	1893 10 28	21 55	14	6441	9	— 9627.2	−15941.0	5 58 48.11	+53 39 46.8	+0.03	−0.1
				6442	9	— 9626.9	−15941.2	5 58 48.14	+53 39 46.7		
I 9832	1893 10 30	20 18	10	6377	9	+ 9760.3	−14440.0	6 4 33.13	+54 6 25.8	+0.03	−1.3
				6378	9	+ 9760.7	−14441.3	6 4 33.16	+54 6 24.5		
I 9862	1893 10 31	21 21	15	6391	7	−10903.8	+ 3653.4	6 7 37.42	+54 20 11.2	+0.40	+2.2
				6392	7	−10900.1	+ 3655.3	6 7 37.82	+54 20 13.4		
I 10095	1893 11 26	20 26	17	6390	7	−15368.2	+ 4066.2	7 17 31.35	+57 49 34.0	−0.29	−1.0
				6389	7	−15370.6	+ 4065.5	7 17 31.06	+57 49 33.0		
I 10215	1893 12 19	18 21	14	6375	4	+10544.4	+ 5340.3	7 45 56.41	+54 38 39.2	+0.28	+0.1
				6376	4	+10546.8	+ 5340.5	7 45 56.69	+54 38 39.3		
I 10280	1893 12 23	19 49	13	6416	4	−10591.8	− 642.9	7 45 57.59	+52 58 16.4	−0.19	−1.7
				6417	4	−10593.7	− 644.5	7 45 57.40	+52 58 14.7		
I 10321	1893 12 27	17 32	10	6383	7	+10580.3	+10362.3	7 44 43.17	+50 55 0.2	+0.03	−0.6
				6382	7	+10580.7	+10361.7	7 44 43.20	+50 54 59.6		
I 10469	1894 1 19	16 57	10	6408	7	− 654.1	−15761.6	7 26 28.40	+28 45 48.4	−0.20	+0.9
				6409	7	− 656.7	−15760.7	7 26 28.20	+28 45 49.3		
I 10559	1894 1 25	16 16	13	6393	9	− 3564.4	+11541.9	7 23 33.46	+21 14 58.0	−0.01	−1.0
				6394	9	− 3564.6	+11541.0	7 23 33.45	+21 14 57.0		
A 222	1894 2 5	15 26	60	6410	7	− 4630.1	+ 5011.8	7 23 17.83	+ 8 45 22.8	−0.05	+1.9
				6411	7	− 4630.8	+ 5013.7	7 23 17.78	+ 8 45 24.7		
A 246	1894 2 16	14 49	12	6414	8	+ 1059.4	− 9589.6	7 29 58.55	− 0 21 42.7	−0.08	+0.6
				6415	8	+ 1058.2	− 9589.0	7 29 58.47	− 0 21 42.1		
I 10685	1894 2 16	14 59	13	6436	11	+10997.4	−13093.8	7 29 59.01	− 0 21 54.4	−0.32	−3.6
				6437	11	+10992.6	−13097.4	7 29 58.69	− 0 21 58.0		
B 10909	1894 4 16	14 13	10	6371	7	+ 2201.3	+13823.8	9 17 0.62	−13 33 54.0	−0.03	+1.8
				6374	7	+ 2200.9	+13825.6	9 17 0.59	−13 33 52.2		
B 10951	1894 4 18	14 29	10	6365	9	+ 8489.9	+12761.3	9 21 47.01	−13 38 52.7	−0.10	+1.3
				6370	9	+ 8488.5	+12762.6	9 21 46.91	−13 38 51.4		
B 11174	1894 5 19	14 16	10	6344	7	+ 7170.1	−10985.5	10 38 1.88	−14 57 21.9	+0.10	+3.6
				6346	7	+ 7171.6	−10981.9	10 38 1.98	−14 57 18.3		
B 15531	1896 4 6	20 52	60	6360	7	− 7958.9	− 3771.5	18 36 59.92	−38 32 48.8	+0.03	+1.0
				6361	7	− 7958.6	− 3770.5	18 36 59.95	−38 32 47.8		
B 16108	1896 6 4	16 40	70	6350	5	−10686.4	− 9103.3	18 30 6.81	−40 2 45.2	+0.75	+0.2
				6351	5	−10677.8	− 9102.7	18 30 7.56	−40 2 45.0		
B 16157	1896 6 5	19 54	10	6355	5	+15242.6	+ 8861.3	18 27 51.27	−39 58 33.0	+0.24	+0.7
				6357	5	+15245.4	+ 8861.9	18 27 51.51	−39 58 32.3		
B 16165	1896 6 5	22 4	11	6353	4	+ 1306.6	− 8891.1	18 27 39.55	−39 58 2.1	+0.07	+3.4
				6354	4	+ 1307.4	− 8887.7	18 27 39.62	−39 57 58.7		
B 16518	1896 6 29	19 17	15	6348	9	− 9732.7	+ 4124.9	17 37 43.91	−36 21 26.7	−0.09	+1.4
				6349	9	− 9733.9	+ 4126.3	17 37 43.82	−36 21 25.3		
A 1876	1896 6 30	13 46	60	6413	6	+ 5864.8	+ 4719.0	17 36 22.23	−36 11 20.9	0.00	+0.5
				6412	6	+ 5864.8	+ 4719.4	17 36 22.23	−36 11 20.4		

method of reduction. The differences in the two results for the right ascension, and for the declination, are given in the last two columns.

On I 9832 the image is irregular. The position of the brightest part is given. The center precedes it 0ˢ.66, and is 8″.6 south. On A 222 and A 1876 the images are much elongated, owing to the motion of *Eros*. The means of the measures of the ends are given. The discordance in the positions derived from I 10685 and B 16108 is probably due to the poor quality of the images.

A complete discussion of these measures, including the original settings and the results for each comparison star, is in course of preparation for the *Annals*. The positions of the stars have been taken from the Catalogues of the *Astronomische Gesellschaft*, except in the

case of the plates taken in 1896 for which the Cordoba Catalogues have been used. The average value of the 296 residuals for the catalogue stars is, for x, $\pm 1''.03$, for y, $\pm 1''.06$. The average difference of the standard coördinates of the two positions of *Eros* is, for x, $\pm 1''.8$, for y, $\pm 1''.4$. For the three Bruce plates these values become $\pm 0''.6$ and $\pm 1''.0$, respectively.

EDWARD C. PICKERING.

June 7, 1900.

Eclipse Reports

PRELIMINARY RESULTS OF THE UNITED STATES NAVAL OBSERVATORY ECLIPSE EXPEDITIONS.

In equipping two stations on the central line, one in North Carolina and one in Georgia, the intention was merely to duplicate the work so as to avoid the danger of cloudy weather. The spectroscopic work of the Georgia station was transferred to a station near Griffin at Experiment, for the purpose of getting near the northern limit of totality to secure as long an exposure as possible on the reversing layer. With the exception of the spectroscopic instruments of the Georgia station, which were at Griffin, the work at the two stations was generally the same.

The general plan of observations at all three stations included a determination of the longitude by exchange of signals with Washington, and the latitude by Talcott's method. This was specially important in the station near the northern limit, as the maps of that region were unreliable, and some time was spent in locating the station, so as to be about three miles from the northern limit. This part of the program was carried out at all three stations, and the results will soon be ready for publication.

The photographic work at both central stations included photographs of the corona with the 5-inch photoheliograph lenses of 40 feet focal length, and with several smaller instruments, some of which were provided with color screens for the purpose of securing photographs of the corona from the light in the green region of the spectrum, and also for testing at the same time their value in cutting down the sky glare in long exposures.

The photographic program was not carried out in accordance with the plans as originally formed, but was modified to make the work on the two stations fill in what was thought at that time to be deficiencies in the work of other eclipse parties. For this reason it was thought advisable to obtain at each station a photograph of long exposure with the long focus lens. The photographs obtained with

each instrument consist of exposures of 2, 5, 10, 35, 45, and 2 seconds, 9 plates altogether. The plates used were Seed's double coated 14×17, backed with a thick coat of artists' lampblack.

While the 2 seconds exposures are too long to show the extreme inner corona and the prominences satisfactorily, they are of value in connection with 5 and 10-second exposures in giving on a large scale the details of the inner and middle corona. Of the two long exposures, that of 45 seconds at Pinehurst caught the first rays of returning sunlight, but both give fine details of the outer corona to a distance of one diameter of the Moon. The last of the Barnesville plates, exposure 2 seconds, also caught the returning sunlight, but shows the prominences and inner corona, close up to the crescent of the photosphere.

Two 6-inch Dallmeyer lenses of 36 inches focus, one of them provided with a color screen containing a solution of picrate of copper, were used at Pinehurst, and the color screen was placed outside of the outer lens. Three photographs were obtained with these of 2, 5 and 40 seconds exposure. On the same polar axis with these two was a short focus Voigtländer lens of 4 inches aperture and 8 inches focal length, with which two pictures were taken; one, with a color screen, of 20 seconds, and the other, without a color screen, of 40 seconds. The placing of the color screen in front of the objective seems to have caused in both of these instruments reflections and distortions of the image to such an extent as to seriously interfere with good definition. All of the four plates of long exposures are rather dark, and show relatively but little extension of the corona, not beyond three diameters.

At Barnesville the five instruments were arranged on the same polar axis; two were provided with color screens similar to those at Pinehurst, with the exception that the color screens were placed inside of the lenses, and the results are very much more favorable. With the 6-inch visual lens of 102 inches focus, the color screen was placed about 18 inches in front of the photographic plate; with the other instrument, a Dallmeyer lens 3.5 inches aperture and 9.5 inches focal length, the color screen was placed just inside the inner lens of the system. With the former of these two instruments was used a 6-inch Brashear photographic lens of 90 inches focus, belonging to Mr. C. A. Post, of New York; and as a companion to the small Dallmeyer lens a similar instrument of 4 inches aperture and 17 inches focal length was used

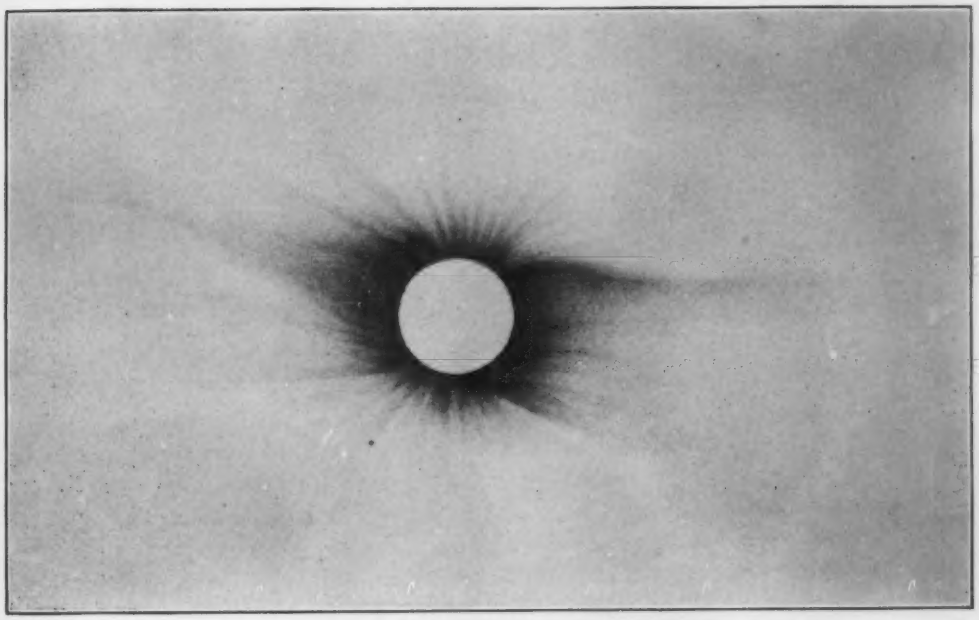
without a color screen. There was further on this axis a 6-inch Dallmeyer lens of 33 inches focus. The exposures with all of these instruments were 2, 5, 5, and 40 seconds, the last one concluding just at the end of totality. This was not intentional, as the long exposure was to have come in the middle of the eclipse, but owing to the time required for the vibration of the axis, caused by changing the plates, to cease, it was found necessary to carry out the program of exposures as given above. The photographs with the 6-inch visual lens, color screen, are very sharp and show a considerable extension of the corona, which apparently differ in no wise from the one taken with the companion instrument except in showing a greater extent of corona. The long exposures, however, show the advantage of the color screen in cutting out the sky glare, thus giving a greater extension of the faint coronal streamers. There also seems to be a greater extent shown of the polar streamers relative to equatorial portions than in photographs taken without the color screen. With the long exposure on the Dallmeyer instrument, however, provided with a color screen, the extension of the corona can be distinctly traced on the west beyond *Mercury*, which is farther, so far as I can learn, than has been obtained elsewhere at this eclipse either photographically or visually. In the companion picture on the 4-inch Dallmeyer lens, the development could not be carried nearly so far on account of the fogging of the plate due to sky glare. Taking all the results together, it seems to me that the experiments with the color screen have yielded sufficient material to warrant its further use at coming eclipses. With the experience gained concerning the position of the screen and the material with which to fill it, there ought to be obtained a greater extension of the corona with the color screen than without it. (Plate III, from drawing.)

SPECTROSCOPIC RESULTS.

In arranging the general plan of observations to be made by the Observatory eclipse expeditions, the spectroscopic work was considered of the highest importance, as the work on the reversing layer is independent of the duration of totality, and an eclipse of such brief duration as the last one has even an advantage over one of long duration for observations of this character.

The instruments employed consisted of a prismatic camera at Pinehurst, a slitless spectrograph at Barnesville, in the line of prismatic spectroscopes; two grating objectives, consisting of a plane grating in

PLATE III



THE CORONA

DRAWN FROM PHOTOGRAPHS BY L. E. JEWELL

combination with a quartz lens, and three concave gratings using slits and quartz lenses for forming the image on the slit plate.

Of these instruments the first of the concave gratings was used by Dr. Ames at Pinehurst with a slit two or three millimeters wide and about one millimeter long. The expedient of using a wide slit was adopted after the instrument had been erected at Pinehurst, on account of the evident difficulty which would be met in bringing and keeping the image of the reversing layer upon the slit. The quartz lens used with this grating, however, was 3 inches in diameter and about 35 inches focal length, from which it is evident that only about one third of the light from the reversing layer would be received by the grating.

The second concave grating was used by Dr. Crew at Griffin with a narrow slit about .05 of a millimeter, and a quartz lens 72 inches focus and $3\frac{7}{16}$ inches aperture.

The third concave grating, one of 21 feet radius, used by Dr. Humphreys of the University of Virginia, also at Griffin, was used in the same manner with a narrow slit.

With none of these concave gratings were any results of value obtained. This, in two of them, is unquestionably due to the fact that the image of the reversing layer was not on the slit during the exposure, while in the case of Dr. Ames at Pinehurst the failure was due, first, to the cause already mentioned concerning the short focal length of the quartz lens, combined with the shortness of the exposure which could be obtained on the reversing layer at a station near the central line of totality. While the failure to obtain results with these gratings is disappointing, it does not preclude their use to great advantage at subsequent eclipses, as a mounting has already been devised which obviates the use of the slit.

The plane grating at Griffin in charge of Mr. Jewell also failed to get any results, but this was due entirely to an unfortunate accident, and in no way reflects upon the capacity of the instrument to give all that was expected of it.

The results with the remaining grating objective, in charge of Dr. Huff at Pinehurst, are sufficiently valuable to show the great advantage of the use of the grating, either plane or concave, in future spectroscopic eclipse work. With this instrument three photographs were obtained: (1) the flash spectrum of the second contact of only 1 second exposure; (2) 25 to 30 seconds later on the corona with an

exposure of only 5 or 6 seconds; (3) Fraunhofer spectrum after the third contact, exposure 1 second.

The plate-holders in all the grating spectroscopes were shaped to the focal curve of the spectrum, and it was expected that all parts of the spectrum would be in sharp focus, but on trial at the eclipse stations it was found that the plates furnished would not bend the required amount, and thus only a limited portion of the spectrum is in sharp focus.

Plate IV shows an enlarged positive on glass of the flash spectrum obtained at the second contact, exposure 1 second, at Pinehurst, N. C. Dimensions of the grating are as follows:

Six-inch flat grating, ruled space 3.5×5 inches, 15,000 lines to the inch. Extremely bright in the first order on one side, and in the second order on the opposite. The spectrum is almost entirely free from diffused light.

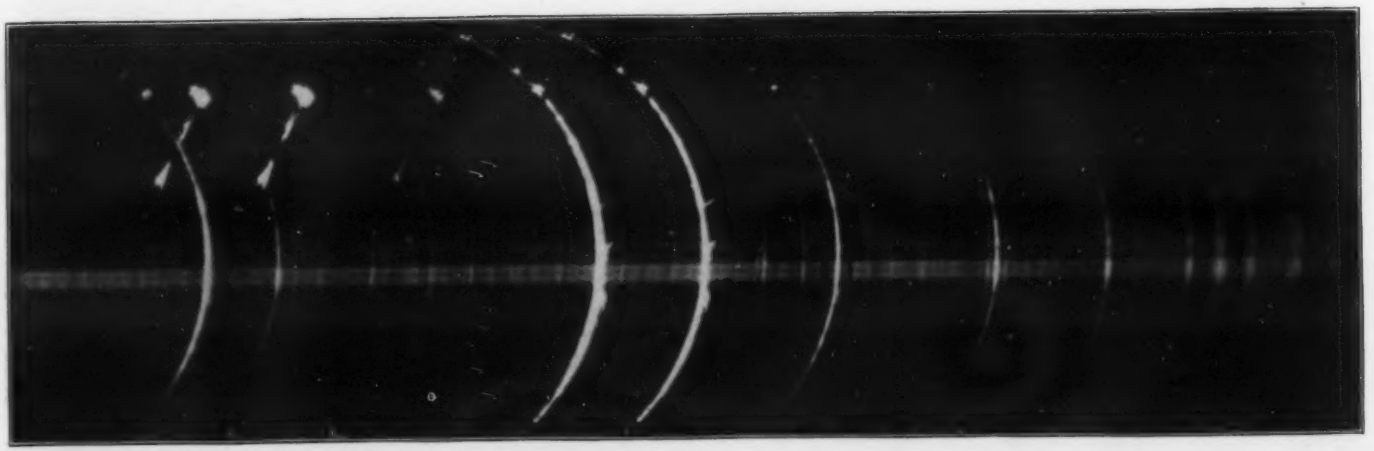
The original photograph extends from wave-length 3000 to 6000, giving a dispersion of about 10 inches. Some of the important facts which may be drawn from a brief inspection of this portion of the spectrum are worthy of attention.

The prominences, as shown in the light of the H and K lines, show details which compare favorably with large scale photographs, and which are rather better than in small scale photographs. The plate shows marked differences in the prominences as given by the lines of helium and hydrogen and those by the calcium lines H and K. The bright horn-like prominences shown in H and K, as well as one entirely detached, are not shown at all in the helium and hydrogen lines. Some of the prominences are shown in the bright strontium line 4078, just above *Hδ*. This is also the case with the titanium lines.

Three of the carbon bands at $\lambda 3883$ show very brilliantly up to a height of 100 to 200 miles, and faintly up to a height of 200 to 400.

Notwithstanding the short exposure of 1 second, considerable detail is shown in the green coronal line 5303, and in the violet coronal line at 3987. The distribution of material producing these two lines is shown to be entirely different, and to have no connection whatever with the prominences, and little, if any, with the material giving the continuous spectrum of the corona. The distribution of material in 3987 is more like that of the matter in the chromosphere than in 5303.

PLATE IV



SPECTRUM OF THE SECOND FLASH

PHOTOGRAPHED WITH AN OBJECTIVE GRATING BY W. B. HUFF

A faint though very remarkable line at 3965, which seems to be strongest at an elevation of from 1000 to 4000 miles, and very weak in lower strata, is scarcely visible in the spectrum of the base of the chromosphere. This has been identified as one of the lines of the "principal series" of *Parhelium* and several lines in Professor Lord's flash spectra, which share the same peculiarity of distribution of light, also are identified as belonging to the same element, but not all to the same series.

The plate shows 20 lines between H and K, and if it had been in focus throughout its length, would evidently have contained about 1500 lines.

In the second plate taken, the coronal lines are well shown, and four new ones have been found in the ultra-violet at approximately 3381, 3456, 3643, and 3801. The line at 3381 is remarkably strong, and indicates a distribution of material similar to that shown by the green coronal line at 5303; while the other three show a similarity in distribution to that in the violet at 3987.

The separating power of this apparatus is well shown by the fact that in the original negative the hydrogen and calcium components of H are distinctly separated.

The plates showing the third contact were spoiled by continuing the exposure after the Sun came out.

On the fourth plate, of the Fraunhofer spectrum, the strong lines are shown bright at the edges of the spectrum, and a displacement is noticeable between the dark and bright portions similar to that shown in Professor Campbell's pictures taken at the 1898 Indian eclipse. The photograph shows definitely that this displacement is due to the fact that the source of the dark and bright lines is different, and is purely an angular displacement, the dark Fraunhofer lines being produced by the photosphere, and the bright lines by the base of the chromosphere at considerable elevation above this. The aluminium and titanium lines also show both the dark lines and the bright extensions, in addition to helium, hydrogen and strontium, though in none of these is there indicated more than a very slight displacement of the dark and bright portions.

The prismatic camera.—This consisted of a 60° prism of 6 inches length and faces 5 inches broad, used in connection with a 4-inch visual lens of 60 inches focus. The plates used were 5 × 7 Erythro, very obligingly sent on a short time before the eclipse by Mr. Douglass.

Although the definition of the plate is not good, due to the curvature of the focal plane, the results are worthy of careful study, as it shows lines between C and K at least 350 to 400 in number, including 6 or 8 between D_3 and C. The exposure on this plate was made at the second contact, and is estimated to have been less than one second, and yet the C line comes out very distinct, bright and extensive. On the second plate, with an exposure of 40 seconds, the clock worked badly, and the lines are somewhat drawn out. There are shown, however, as dark lines, the various groups of lines due to the Earth's atmosphere, including *a*, B, *a*, A, and traces of atmospheric lines hear D.

The following preliminary report was prepared by Professor Lord:

In the jacket which carries the two-prism star spectroscope of the Emerson McMillin Observatory (see this JOURNAL, Vol. IV, No. 1) was securely fastened the tube of a 4-inch Clark telescope of about 60 inches focus. This formed an image of the solar crescent at the point ordinarily occupied by the slit. The jacket itself was screwed into a cast-iron ring similar to the breach piece of the 12-inch telescope, except that at the opposite ends of a diameter there were two trunnions fitting into boxes securely bolted to the heavy wooden stand that carried the instrument. Thus the whole spectroscope could be rotated about the axis of collimation of the 4-inch objective, and at the same time the entire instrument, objective and all, could be rotated a small amount about a line at right angles to it. At a point midway between the two trunnions a lug projected from the supporting ring, which carried at its extremity a screw, whose axis was perpendicular to the plane of the ring and whose end butted against the support of the instrument. This screw served not only to rotate the entire instrument about a line perpendicular to the axis of collimation but also gave a rough means of measuring the amount of this rotation. The 4-inch telescope was fed by a most excellent coelostat, kindly furnished by the Naval Observatory. The axis of the trunnions was placed perpendicular to the line joining the points of the second and third contacts as seen in the mirror of the coelostat. Thus it was possible during totality, first, by a rotation of this screw, and second, by a rotation of the spectroscope in its jacket, to so move the instrument that the image of the point of third contact could be made to fall accurately at the point ordinarily occupied by the center of the slit, and, at the same time, to bring the image of the tangent to the solar crescent at this point parallel to the refracting edge of the prism. At Barnesville, though the change in position angle was considerable, it was decided not to attempt the second change but simply to shift the instrument during totality from one limb of the Sun to the other, one and a quarter turns being necessary.

In order to check all adjustments the telescope which receives the light reflected from the front face of the first prism and is used for following in photographing stellar spectra had two wires placed in its eyepiece, one parallel and one perpendicular to the slit. Thus before totality the instrument could be accurately directed to the point of second contact. During totality the screw was given a turn and a quarter by estimation, and when examined after the eclipse through the following eyepiece the point of third contact was found accurately at the intersection of the two wires.

The framework which carried this somewhat heavy piece of apparatus was built of heavy timber in the form of an isosceles triangle, having two uprights at the center of each leg to which the boxes of the iron ring were fastened. The vertex of the triangle extended about 18 inches in front of the 4-inch objective and was pivoted under the center of the coelostat mirror. The base rested on a heavy beam. Thus the entire instrument could be rotated in azimuth through an angle of about 30°. In this way, not only could the Sun be followed from day to day but bright stars could be photographed for purposes of adjustment. To show the necessity of such a plan of adjustment I will only state that within 10 minutes of totality, as I gave a last look at my adjustments, I discovered that the Sun's image was not exactly centered and it was necessary to move this entire framework; this was successfully done in ample time for the second contact.

I desired to secure a number of photographs both before and after the flash. In order to accomplish this I fitted a sliding plate-holder to the end of the camera. This consisted of a slide carrying the plate-holder mounted on bicycle balls, which traveled in V-shaped ways. The slide was forced against these by means of two wheels kept pressed against the back face of the slide by a couple of spiral springs. The carriage carried an escapement operated by a pneumatic release, so that by pressing a bulb the plate was automatically shifted $\frac{1}{8}$ of an inch in less than $\frac{1}{3}$ of a second. The size of the picture was $\frac{1}{2} \times 2$ inches. The jar was taken up by a sliding brace from the end of the camera to the solid woodwork of the frame, so designed that it was only necessary to clamp or loosen a single thumbscrew to make the brace either rigid or flexible in every direction. The carriage was so mounted that it could be tilted in a direction parallel to the length of the spectrum in order to accommodate outstanding chromatic aberration.

In front of the objective a rough wooden shutter served for purposes of exposure. The shortest exposure possible was about $\frac{1}{3}$ of a second, which, however, the plates show was much too long for the solar crescent before totality.

After a good many trials I was convinced that it would be impossible to follow any time schedule for exposures and I adopted a suggestion made by Dr. Crew to watch for the flash and expose when I saw it, making one or two

exposures before and after, those preceding the flash to be as short as possible. As I had no additional spectroscope, it was necessary to build one out of what extra apparatus I happened to have. To do this, I used a 60° dense flint prism and the observing telescope of the spectroscope. This prism was mounted as an objective prism, the whole in a rough alt-azimuth stand. It worked most satisfactorily, as the entire process of the change, from the continuous spectrum long before totality to that of mid-totality, was easily observed and constituted one of the most beautiful sights that I ever hope to witness. I did not attempt to secure the times at which the exposures were made as I had no means of automatically recording them.

The program of exposures as actually carried out was as follows: With the string which operated the exposing shutter in one hand and the bulb which shifted the plates in the other, I watched the spectrum through the objective prism spectroscope. By six and one half minutes before totality the dark $H\beta$ line was faintly shown; three minutes later numerous lines began to appear. Shortly before totality $H\beta$ was brilliantly reversed and exposure No. 1 was made. The spectrum then rapidly narrowed and plate No. 2, snap exposure (about one third second) was made. The spectrum continued to narrow until it suddenly broke up into a number of bright strips extending the length of the spectrum; with this came the flash, and No. 3 was exposed. I had intended at this point to leave the objective open until the flash disappeared, but habit was stronger than purpose, and I involuntarily made a snap shot at this point. I instantly remembered myself and again opened the objective, so I feel safe in saying that I did not lose over one third of a second by this mistake. It is, however, in my judgment, rather fortunate that this accident happened, as it throws some light on the duration of the flash. Plate No. 6 had full exposure on the flash, and yet does not show much greater exposure than 3, which would tend to show that the duration of the flash was considerably under one second. The appearance of the flash itself was very peculiar, though the entire phenomenon was excessively short. My notes made at the time say, "Could not have been over one second." It was not fixed while it lasted, but the lines seemed to twinkle. As soon as the flash disappeared exposure No. 4 was made for about three seconds. As the slide was only arranged for four exposures, the plate-holder was changed, the slide set, and the instrument directed to the point of third contact. So intent had I been on watching the spectrum through the objective prism that I had been oblivious to the count, and fearing I was late I listened and heard 33–34 with a great sense of relief. I at once opened the 4-inch, thus exposing No. 5, and turned to look at the corona, which I watched until 60 was called. When I turned back to the objective prism I was at once struck with the great brilliancy of the $H\beta$ line, which showed several well-marked prominences, when I felt it was time to shift the plate without closing the 4-inch, and this exposure

PLATE V

SPECTRUM OF THE SECOND FLASH

PHOTOGRAPHED WITH OBJECTIVE-PRISM TRAIN BY H. C. LORD

was continued as long as seemed safe and until the flash was well developed. The objective was then capped and the plate shifted, but I made a double shift at this point, so that I had but one plate left to expose after the third contact. This exposure was made almost immediately following the flash; it was of about one third of a second duration, and is No. 8 on my list, No. 7 being a blank.

The plates were not developed until after my return to Columbus. The most noticeable feature common to all was the great amount of continuous spectrum. This was certainly *not* due to the light leaking through the apparatus, as this point had not only been carefully tested, but the portions of the plate between exposures showed not the faintest trace of fog. Plate No. 1 was much overexposed, but showed in addition to a number of the dark Fraunhofer lines the $H\beta$ brilliantly reversed on the edges and dark in the center. The dark $H\beta$ fades into the bright one, but the lines do not butt against each other, but overlap so that for a considerable extent the bright and dark lines are seen side by side like the pieces of a spliced rod, except that the prolongation of the dark line does not pass through the center but to one side of the bright line. The same thing is shown in a few of the other lines, but is not nearly so well marked. No. 2 shows a number of bright lines bordering a continuous overexposed spectrum containing only a very few dark lines. D_3 is bright clear across the continuous spectrum. No. 3 is the flash and shows 150 lines from D to near $H\gamma$. No. 4 shows only a very few bright lines. No. 5 the same. No. 6 is the flash at third contact and shows over 157 lines. (Plate V.) No. 8 shows quite a number of bright lines bordering the continuous spectrum, which, as in No. 2, shows almost no dark lines.

The visual observations of Mr. Jewell at Griffin, with a small grating binocular, are interesting and valuable, as the long duration of the reversing layer so near the limit of totality gave time for observing carefully the gradual appearance and disappearance of the bright lines of its spectrum. The instrument consisted of a plane grating, one inch square, of 15,000 lines, and a small plane metallic reflector in combination with a field glass magnifying three diameters.

At five minutes before totality the Fraunhofer lines were arranged in dark narrow crescents, too bright in the yellow to observe comfortably, and observations were confined to the blue-green region in the vicinity of F.

At two and one half minutes before totality the F line was seen tipped on the lower end with a bright point which spread gradually upward, and a minute later a similar appearance was noticed on the upper horn. The spectrum band gradually narrowed, until five seconds before contact the arcs of the Fraunhofer spectrum embraced about

one fourth of the Sun's diameter. At three seconds before contact the mountains of the Moon began to break through and cut across the crescents, and an observer stationed near by signaled the appearance of the shadow on a range of hills six miles distant. At the same time many of the fairly strong lines became brightly tipped at the ends of the crescents; the Fraunhofer spectrum began to narrow rapidly, until when a very narrow ribbon was left it changed to a bright streak which seemed to remain thus for about a second and then disappeared.

At this instant the signal for totality was given, which coincided exactly in time with that given by myself observing with a six-inch telescope. The field of the spectroscope was now literally filled with bright crescents of various lengths which faded out very gradually, many of them lasting eight or ten seconds after second contact, and a few even longer.

At mid-totality the F line was visible, forming a bright arc of from two thirds to three fourths of a complete circle, as well as several other much fainter lines including the *b*'s.

At ten seconds before the third contact other bright lines began to appear, and the phenomena at the beginning were repeated in reverse order.

The appearance and disappearance of the fine bright short lines was not instantaneous, but gradual. The narrow bright streak seen at the instant of both contacts was without doubt the narrow band of short bright lines shown in the photographic spectrum of the reversing layer at second contact, due in great part to matter at a height of 100 to 300 miles above the photosphere, along with a considerable amount of continuous spectrum.

These observations, taken in connection with the statement of Dr. Gilbert, that the exposure for the spectrum obtained at the second contact *ended* just before the last rays of direct sunlight disappeared — and the further evidence of the large scale photographs showing the base of the chromosphere and a very small portion of the photosphere — indicate that the chromosphere at its base is very dense and bright, and weakens gradually towards its upper limits, at its base merging gradually into the upper limits of the photosphere.

The great advantage of a station near the outer edge of the shadow path is shown by the ease and distinctness with which the spectrum of the chromosphere was observed at Experiment, compared with the failure of two observers at Pinehurst, using instruments of identical

construction, to see it at all, and the experience of Professor Lord at Barnesville, who observed it with a more powerful instrument, a prismatic camera, but found it surprisingly faint.

Of visual observations, besides the observations of contacts, naked-eye and telescopic drawings of the corona were secured, three of which are of much merit. These, as well as all the photographs, show the striking similarity between the coronas of 1878 and 1900.

Observations of the shadow bands were secured at many places from Georgia to the coast. While some of the observations are apparently conflicting, there seems to be no doubt from a study of their irregular structure and motion at the many stations that they are of purely atmospheric origin, and will probably find their explanation in the same causes that produce the twinkling or scintillation of the stars.

S. J. Brown.

A PRELIMINARY STATEMENT OF THE RESULTS OF THE SMITHSONIAN OBSERVATORY ECLIPSE EXPEDITION.[1]

In accordance with a special act of Congress, the Astrophysical Observatory of the Smithsonian Institution was enabled to send an expedition to observe the total eclipse of May 28, 1900. This expedition was directed and the preliminary arrangements for it were made by Mr. S. P. Langley, Secretary of the Smithsonian Institution, the field work and immediate supervision being in charge of the writer. The party consisted of fourteen persons, and the site chosen for the observations, which was selected not only after consideration of the Weather Bureau's reports for the eclipse belt, but also after a careful examination of various localities, was Wadesboro, N. C. The instruments and equipment were placed upon ground most generously offered for the purpose by John Leak, Esq., of Wadesboro, to whom and to many other citizens of the town are due hearty thanks for the hospitality enjoyed there by the large number of visiting astronomers. The Yerkes Observatory party was on the same ground, and there were also in Wadesboro expeditions from the Princeton Observatory and from the British Astronomical Association, making in all a most pleasant international gathering.

As the most thorough preparation and drill was recognized by Mr. Langley to be one of the prime conditions to success in eclipse observations, several months were almost wholly devoted to preparing for

[1] Published by permission of the Acting Secretary of the Smithsonian Institution.

the expedition. The whole outfit was set up upon the green south of the Smithsonian building, in Washington, early in April, and preliminary experiments and even two practice eclipses, in which actual photographs were taken, were carried through there. The apparatus was removed to Wadesboro very early in May and reached the grounds May 7, and here also all things were tested and drilled, that nothing might be lacking to a satisfactory result. On the morning preceding the eclipse a "full-dress rehearsal" took place, at which every detail was attended to as if the phenomenon was actually occurring, Mr. Langley remarking that if a pin was going to fall and be picked up during the eclipse it should be dropped and picked up for practice in that rehearsal.

The main object of investigation of our party was the corona, and of this it was desired, first, to obtain large-scale photographs of the inner details, with other photographs showing the extent of the corona, and second, to examine the inner corona with the aid of the bolometer to obtain thermal evidences of coronal radiations and, if possible, of the form of its prismatic spectrum energy curve.

In addition to these investigations, five cameras of large field were used to photograph the region around the Sun, visual telescopic observations and sketches were made, and the times of contacts were observed visually and with a camera exposed each second by a chronometer. An objective prism used in connection with the 135-foot focus camera was used also with an automatic exposure to obtain the flash spectrum at second contact.

Before proceeding further it may be said that all these investigations yielded interesting results excepting the last, which from some unknown cause was unsuccessful.

I will now briefly describe these several kinds of observations, the instruments employed in them, and their results.

I. DETAIL PHOTOGRAPHS OF THE INNER CORONA.

Mr. Langley had long been specially interested in the details of structure of the inner corona in consequence of the surprising definiteness in this respect noted by him in visual telescopic observations made at Pikes Peak in 1878. While knowing and admiring the fine photographs of Campbell, and earlier of Schaeberle, with a 5-inch 40-foot focus lens, it was his belief that still more of structure might be obtained with an instrument of greater aperture and focal length. He

PLATE VI

THE NORTH POLAR STREAMERS OF THE CORONA

PHOTOGRAPHED WITH A 12-INCH TELESCOPE OF 135 FEET FOCAL LENGTH BY T. W. SMILLIE

was on the point of ordering a lens of 8 inches aperture and 60 feet focus for this purpose, when he received the extremely welcome offer of Professor E. C. Pickering of the loan of the new 12-inch achromatic lens of 135 feet focus belonging to the Harvard College Observatory. At the same time, Professor Pickering offered several other pieces of optical apparatus, including that for the automatic flash spectrum with the objective prism. It is needless to say that this most generous offer was accepted.

In addition to the great 12-inch lens, one of the set of "Transit of Venus" lenses, of 5-inch aperture and 38-foot focus, was used through the kind offices of Professor Young, of Princeton.

The former was employed as a horizontal telescope in connection with the 48-hour polar axis type of coelostat carrying an 18-inch plane mirror, while the latter was pointed in a stationary position toward the sky and the photographic plate moved in the focus by a water clock. The first instrument had 30-inch square plates, and was manipulated by Mr. T. W. Smillie, of the United States National Museum (who also had general charge of photography, including the development of all plates), and the second, employing 11 × 14 plates, was in charge of Mr. F. E. Fowle, Jr. The plates used, not only in this but in all the photographic work, were Cramer double coated isochromatic plates, not backed. They were extremely rapid, being for general purposes nearly twice as fast as Seed's 26x ordinary.

Six exposures were made by Mr. Smillie during totality, ranging from ½ second to 16 seconds. All these were entirely successful. Three others made after totality showed little of interest. The illustration (Plate VI) is from a print of the 16 seconds exposure. All the original plates (on a scale of 15½ inches for the Moon) are full of detail, the prominences being very striking. There seems to be no question that the details are more numerous than those shown upon the smaller scale of the 38-foot lens.

Mr. Fowle obtained seven negatives with this latter instrument during totality, all of which are excellent. The times of exposure varied from ½ to 8 seconds. The 8 seconds exposure shows the corona somewhat further than the 16 seconds exposure with the great lens.

II. BOLOMETRY OF THE INNER CORONA.

This was in the hands of Mr. C. E. Mendenhall and myself, he reading at the galvanometer, I manipulating the optical apparatus. As

the results obtained seem to be of importance in their bearing on the composition of the corona, a diagram of the apparatus is inserted (Plate VII) that a clear understanding of the experiment may be obtained.

The light from the Sun, falling upon the plane siderostat mirror of 17 inches aperture, passed first through a cats-eye diaphragm of gray cardboard controlled by Mr. Mendenhall. Thence it fell upon a 50 cm mirror of 1 m focus, and came to a focus upon the slit, 1 cm high, 1 mm wide, in the optical axis of the mirror. Behind this slit was a little plane mirror which reflected the beam out of the path of the entering light to a second plane mirror, thence to a concave, of 26 cm aperture and 75 cm focus, acting as a collimator.

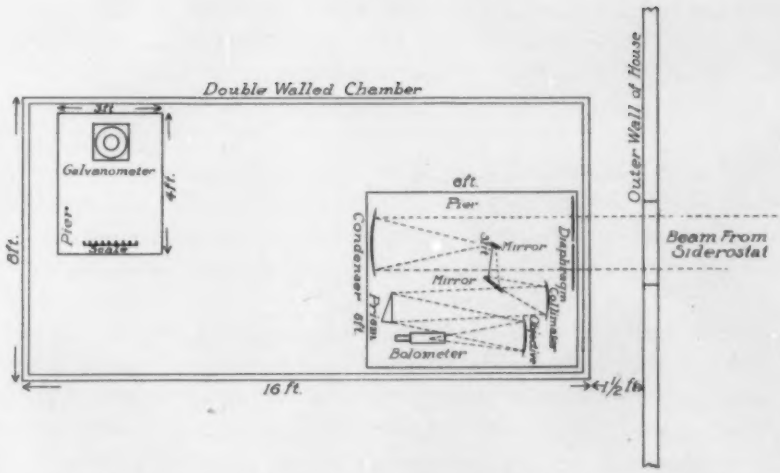
Thence the beam passed to the prism silvered on one face which was intended to serve either of two purposes as desired: to refract or merely to reflect the beam to the mirror of 26 cm aperture and 75 cm focus which formed the image on the 1 cm high, 1 mm wide bolometer strip. There was no plate of glass or other material in front of the bolometer during the experiments, as the galvanometer was found steady enough without, nor was any water in the bolometer water-jacket, as no "drift" was encountered. The case of the bolometer had a conical blackened opening just taking in the cone subtended by the image-forming mirror. A dark gray card was sometimes inserted before the bolometer to give a zero reading. The resistance of the bolometer strip was 0.5 ohm and the current flowing through it 0.2 ampere. The strip was well smoked with camphor smoke.

I have been thus particular to specify details, as I regard them necessary to an intelligent criticism of the results to be described.

About five minutes before totality the image of the diminishing crescent was brought almost tangent to the bolometer strip, and the silvered face of the prism turned to the beam. With the diaphragm aperture at 0.4 sq. cm, galvanometer deflections diminishing from + 60 to + 6 mm were obtained in the next few minutes, the last being about 40 seconds before second contact. The zero of the series was obtained by inserting the gray card above mentioned.

Immediately after totality, the diaphragm having been enlarged to 280 sq. cm aperture, a deflection of — 13 mm was obtained in the same place, *i. e.*, the inner coronal region, and upon turning the Moon's

PLATE VII



BOLOMETER HOUSE OF THE SMITHSONIAN PARTY

dark image upon the slit by means of the adjusting screw of the condensing mirror, a deflection of — 18 mm was observed.[1]

Resetting upon the inner corona, the glass face of the prism being now turned to the beam, and H and K of the spectrum being on the bolometer, no deflection was observed.

These observations seem to me to yield the following results:

1. The coronal radiation was recognized by the bolometer, and gave at least 5 mm deflection over that of the dark Moon.

2. The radiation reflected by the Earth's atmosphere during the partial phase is vastly more intense than that of the corona.

3. *The corona is effectively cooler than the bolometer, and appears, therefore, neither to reflect much light from the Sun nor chiefly by virtue of a high temperature to give light of its own, but seems rather to be giving light in a manner not associated with a high temperature, or at least with the preponderance of infra-red rays usual in the spectra of hot bodies.*

As the last statement involves a rejection of both the eruptive and meteoric coronal theories, it ought to receive searching criticism, and the experimental observations on which it rests ought to be verified at future eclipses. The statement depends on the following experimental evidence:

The corona gave a negative deflection with respect to a card and to the walls of the room as reflected by the glass prism surface, both being supposed to be at the same or a lower temperature than the bolometer strip. From this it follows that the bolometer strip was losing energy by radiating toward the corona, not the corona toward the strip. That the card, the walls of the room reflected by the glass prism surface, and the bolometer were all of the same temperature, is open to question. But they were all in a fairly constant temperature double-walled room, close together, and all at the same height from the ground. The bolometer strip, however, may probably have been a little *warmer* than the others, for it had constantly passing through it the current of 0.2 ampere. Hence it would appear most probable that the card reading was not the true zero which would be given by a body at the temperature of the bolometer, but a negative value, and

[1] Owing to a slight maladjustment of the condensing mirror not noticed till it was too late to change, the image of the Moon fell a little too low at the slit, so that a little of the polar corona fell on the bolometer strip during the Moon exposure, and hence the negative deflection of 18mm should be numerically increased slightly.

that in consequence the negative deflection recorded from the corona should have been numerically still larger.

I am unaware of quantitative experimental investigations on the heating effects of radiations emitted from the spark and glow electrical discharges in high vacua, from phosphorescent substances, from so-called luminescent substances, from the aurora and other such supposedly cold sources, excepting the investigation[1] of S. P. Langley and F. W. Very on the "Cheapest Form of Light," in which they show a nearly complete absence of radiations other than visible ones from the tropical insect *Pyrophorus Noctilucus* Linn. But it is generally supposed that the quality of radiations emitted by the sources of light I have mentioned is not similar in nature to that of heated bodies in having associated with the light emitted a preponderance of long wave-length rays.

It is hoped to investigate here the glow and spark electrical discharges with a view to their possible bearing on the coronal observation I have just recorded.

It may not appear conclusive to some that these results are inconsistent with the supposition that the corona gives light by reflection, or by the radiation of heated particles, nor do I wish to make a dogmatic statement to this effect. Evidently it is not inconsistent with the experiment that a small portion of the coronal light may be due to these sources, but that most of it is thus caused I am unable to reconcile with the observations. For we know that the full Moon is intrinsically less bright than the inner corona and the daylight sky not much more bright. Both these bodies give light by reflection from the Sun, and both give large positive deflections with the bolometer, chiefly caused by the preponderating amount of infra-red rays they reflect. How then can the corona be composed of particles sufficiently numerous to give a practically continuous surface brighter than the Moon if it shines by light reflected from the Sun, and not give a large positive indication at the bolometer? Again, as regards incandescent particles, we know that white light due primarily to high temperature is invariably associated with a far larger proportion of infra-red rays. How is it possible that incandescent particles sufficiently numerous to give the coronal light should not give bolometric evidence of their high temperature, but rather give the appearance of being cold?

The bolometric study of the Moon may suffice to illustrate either the reflection or incandescence theories. For the Moon is but a mirror

[1] *Am. Jour. Sci.*, 40, 97, 1890.

reflecting light from an incandescent body, the Sun. The bolometric studies of Langley (*Mem. Nat. Acad. of Sci.*, Vol. III, p. 24, 1884) have shown that with fairly similar arrangements to those used at Wadesboro the full Moon's reflected visible rays plus her reflected invisible rays gave enormous positive deflections. How then can a beam from the corona containing at least an equal amount of visible rays give so much less a deflection, except the infra-red rays be absent? If this be the explanation, the radiations of the corona are not of the quality ordinarily emitted by a heated body.

Additional evidence against the theory of reflecting particles is found in the Indian eclipse spectroscopic results of Campbell, who found a continuous spectrum from the inner corona with total absence of dark lines.[1]

If, then, an investigation of glow electrical discharges in high vacua should be found to yield effects approximating those of the corona, it would seem plausible to adopt this explanation of coronal light.

III. PHOTOGRAPHS OF THE OUTER CORONA AND SKY NEAR THE SUN.

Four photographs of the outer corona were obtained. The instruments used were: first, an equatorial of 6 inches aperture and 7½ feet focus, in charge of Mr. De Lancey Gill, used with color screen cutting off the violet; second, two Ross lenses of 4½ inches aperture and 3½ feet focus, one of which had a color screen; and, third, one of a pair of 3-inch lenses of 11 feet focus. The two Ross lenses and the two 11-foot lenses were mounted on a polar axis with excellent clockwork and were designed to search for possible objects of interest near the Sun. They were in charge of Rev. G. M. Searle, C.S.P., assisted by P. A. Draper and C. Smith. Incidentally they give a test of the advantages of the long and short focus for star photographs on a fairly light sky. All the instruments just mentioned were given an exposure of 82 seconds.

The four coronal photographs showed an extension of about three diameters, that with the 7½-foot focus lens being slightly longest while that with the 11-foot focus lens showed best detail.

The two 11-foot focus lenses (covering together a field of 25° × 10° or thereabouts in the equatorial region of the sky) showed most stars, reaching, I think, the seventh magnitude and possibly fainter. The Ross lenses got no farther than the sixth magnitude, but their plates were not as favorably developed. No search has yet been made for new objects.

[1] This JOURNAL, April 1900.

IV. VISUAL OBSERVATIONS.

Visual observations of the corona were made by Secretary Langley, observing, through the courtesy of Professor S. J. Brown, astronomical director of the Naval Observatory, with the 5-inch equatorial formerly used by him on Pikes Peak and reëmployed with the especial intention of enabling him to compare his observations on this occasion with those made in 1878, and by Mr. R. C. Child, with a 6-inch equatorial. Their observations showed little detail in the coronal structure compared with that formerly noted. Mr. Child, before having seen photographs, prepared from his sketches an excellent picture in pastel of the corona, and this is strikingly like the photographs subsequently developed.

Mr. G. R. Putnam, of the Coast Survey, detailed for latitude and longitude observations, determined times of contact and gave signals to the other observers. It appears from his observations and those of Rev. Fr. Woodman that the duration of totality was not appreciably different from that which had been computed from the American ephemeris. Mr. Putnam's latitude and longitude, the result of five nights observations with a reversible meridian transit instrument, was as follows:

Latitude, 34° 57′ 52″ North.

Longitude, 80° 04′ 27″ West of Greenwich.

The photographic time of contact results are not as yet reduced.

On the whole the results of the expedition are satisfactory. Those of chief importance now appear to be:

1. The bolometric examination indicates that the coronal light is not chiefly due to reflecting or incandescent particles, and that its radiations, though measurable, are extremely slight.

2. The 12-inch 135-foot telescope with coelostat proved well adapted to securing detailed photographs of the inner corona, and six excellent photographs have been obtained with this instrument.

3. The plan outlined in a recent Harvard College Observatory *Circular* for photographing faint objects in the sky near the Sun at the time of the eclipse gave good results in practice, seventh and possibly eighth magnitude stars having been photographed over a region 25° × 10° in the direction of the Sun's equator.

C. G. ABBOT.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY,
Washington, D. C., June 30, 1900.

ECLIPSE OBSERVATIONS BY THE PRINCETON PARTY AT WADESBORO, N. C., MAY 28, 1900.

IN this short notice I confine myself to the mere statement of results, without unnecessary details as to instruments, corrections applied, etc.

The weather was almost ideally perfect. What wind there was was very light and changeable.

CONTACTS.

The first contact was observed by myself with 3-inch Fraunhofer at $7^h\ 36^m\ 02^s$. E. St. time; by Professor Reed with 4-inch telescope at $7^h\ 36^m\ 01^s.4$; by Mr. Russell, spectroscopically, by disappearance of C-line in chromosphere spectrum, at $7^h\ 35^m\ 57^s.4$. A series of photographs were also taken by Professor Brackett and Mr. McClenahan with the 12-foot telescope (aperture cut down to 4 inches). The negatives have not yet been measured, but show that *photographic* contact occurred between $35^m\ 54^s$ and $36^m\ 04^s$, the indentation on the Sun's disk being barely perceptible upon the negative taken at the latter moment.

The time of contact, computed from the data of the American Ephemeris, was $7^h\ 36^m\ 09^s.3$, *i. e.*, $7^s.6$ later than the mean of Mr. Reed's observation and my own.

The times of second and third contacts were not noted with precision, as all the observers were otherwise engaged.

The fourth contact was observed by me at $10^h\ 05^m\ 39^s.9$, and by Mr. Reed at $05^m\ 39^s.6$. The observation was easy and very satisfactory. Mr. Russell noted it spectroscopically, as before, at $05^m\ 41^s$. The computed time was $10^h\ 05^m\ 43^s.0$, the difference between computation and observation being now only $3\frac{1}{4}$ seconds.

A series of photographs of the last contact was also taken by Professor Brackett at intervals of 10 seconds. As it was inconvenient, on account of the elevation of the telescope, to make "instantaneous" exposures, the exposures were made of about half a second each, giving *positives* (not *negatives*) of the Sun's disk. The photographs are sharp, and clear, and show by inspection (they are not yet measured) that the contact occurred very nearly at $10^h\ 05^m\ 40^s$. The Moon's indentation is clear on the plate exposed at $05^m\ 34^s$, and has disappeared at $05^m\ 44^s$.

PHOTOGRAPHS OF THE CORONA.

With the 12-foot telescope (driven by clockwork) six photographs of the corona were obtained by Professor Brackett and Mr. McClenahan, with exposures of 1^s (2 plates), 5^s, 10^s, 20^s, and 4^s, the last just as the Sun was reappearing. All except the 5^s negative are good. Professor Libbey had three cameras mounted on a single clock-driven polar axis, one with a landscape lens having an aperture of 4 inches; the other two, photographically corrected telescopic object glasses, with an aperture of 2¼ inches, all having focal lengths ranging 30 to 32 inches. With these he obtained 11 negatives with exposures of 20^s, 10^s, 5^s, and 1^s. The landscape objective (used without a stop) did not perform well for the purpose, but the other negatives are all good, and the 20^s-plate shows the faint extensions of the corona to a distance of two and a half solar diameters, about two thirds as far as the eye could follow them; that is to say, on the photograph the western fish-tail of the corona extends about half way to the planet *Mercury*, while the eye could follow it at least three-quarters of the distance, and with the long, pointed, eastern cone the case was similar.

DRAWINGS OF THE CORONA AND PROMINENCES.

During the totality Professor Magie studied the region near the Sun's limb with the 4-inch telescope with special reference to the connection between the prominences and the corona, and to the details of the coronal filaments where they issue from the Sun. Very little, however, could be made out. The sketches of the corona show an unusually close correspondence with the form shown on the photographs.

THE FLASH-SPECTRUM.

This was observed by Professor Miller, of Cleveland, O., with a slitless spectroscope having the dispersive power of two 60°-prisms of 2 inches aperture, and a small telescope magnifying 11 times. He did not see any very large number of bright lines, though the transition from the dark-line spectrum to the bright lines was sharply marked, and at that moment he gave the signal as the beginning of totality. At mid-totality eight bright rings were visible, but all of them were incomplete — open for about 40° or 50° on the western edge. The explanation is not yet obvious. The "rings" seen were, however, probably all of them chromospheric except the one in the green.

OBSERVATIONS OF THE CORONA SPECTRUM.

These all failed; that is, neither Mr. Russell nor myself could see the bright line of the corona spectrum, nor could Professor Reed get its impression on his photographic plate. The line was doubtless very much fainter than in 1869, 1870, and 1878, when I had not the least difficulty in observing it with an instrument certainly not superior to that used by Mr. Russell. I had not anticipated any such difficulty on this occasion, and the program had been planned with reference to getting a good determination of the line's position rather than merely making it visible.

I worked with an integrating spectroscope, with a diffraction grating of 14,000 lines to the inch, using the second order spectrum, which was very bright. At Princeton I had no difficulty on cloudy days in observing with this instrument the dark 1474 line in the sky spectrum; but during totality I saw absolutely nothing except a very faint continuous spectrum even when the slit was opened to its widest.

Mr. Russell's experience was similar, using an ordinary solar (grating) spectroscope, attached to a telescope of five inches aperture. Before totality began, 1474 and the *b*'s were conspicuously reversed, and at the moment totality began, some fifteen or twenty other lines in the field of view became bright for a second or two — but the corona line did not appear at all: the field was blank, except for the faint continuous spectrum.

Professor Reed's instrument had the same train of four compound prisms which had been loaned to Professor Campbell in 1898, and used by him successfully in photographing the corona line in the Indian eclipse — the plate showed nothing. Possibly the slit was too close — the comparison spectrum was beautifully sharp — and very likely, if we could have had an exposure of six minutes instead of only ninety seconds some impression might have been made.

THE SHADOW BANDS.

These were satisfactorily observed by Mr. Reilly, Mr. Erdman, and Mr. Meier upon two tent-flies, one inclined and nearly facing the eclipsed Sun, the other lying upon the ground. The bands first appeared about a minute and a half before totality, lying in a plane nearly tangent to the uneclipsed arc of the Sun's limb, about two inches wide, but wavy and irregular, separated by an interval of from five to seven inches, and moving with a speed of about five or six miles

an hour, in a direction from southwest to northeast. As totality approached, the interval between the bands diminished, till they were only an inch or two apart, and the speed of their apparent motion increased enormously — to the velocity of an express train. After totality they were more irregular, close together, with no decided progressive motion, but simply quivering or oscillating. They lasted about a minute and a half before fading out. Mr. Reilly attempted to photograph them upon the inclined tent-fly, but got nothing.

It is noteworthy that the motion (real or apparent) observed at our station before totality was exactly opposite in direction to that noted by the Smithsonian observers less than a quarter of a mile away.

C. A. YOUNG.

PRINCETON, N. J.,
June 30, 1900.

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO.

BULLETIN NO. 14.

OBSERVATIONS OF THE TOTAL SOLAR ECLIPSE OF MAY 28, 1900, AT WADESBORO, N. C.[1]

THE Yerkes Observatory eclipse party occupied an excellent site adjoining that of the Smithsonian Institution at Wadesboro, N. C., for the use of which we are indebted to Mr. John Leak. The latitude of the site was determined by Professor A. S. Flint, of the Washburn Observatory, who was a member of our party, but as his observations are not yet reduced, the results here given are based upon the following determinations of position made at the Smithsonian site by Mr. G. R. Putnam of the U. S. Coast and Geodetic Survey:

$$\phi = 34^\circ\ 57'\ 52''\quad \text{N.}$$
$$\lambda = 5^h\ 20^m\ 17^s.88\ \text{W}$$

[1] As it was not definitely known until after the middle of April that it would be possible to send out an eclipse expedition from the Yerkes Observatory, the work of preparation was very hurriedly done. For this reason the instrumental equipment was less complete than it would otherwise have been, and many appliances for facilitating the observational work could not be provided. Special credit is due to Mr. G. W. Ritchey, Superintendent of Instrument Construction, not only for designing most of the instruments and buildings required, but also for superintending their construction at a time when the optical work demanded his constant attention.

CONTACTS.

Contacts were observed by Professor Flint from a station near the coelostat with a 3-inch equatorial of 46 inches focal length, power 50. The chronometer, Bliss 2791 on sidereal time, was loaned by the Washburn Observatory. The observer's primary duty was to call out every 5 seconds of elapsed time for control of the spectroscope exposures made by Professor Frost and Dr. Isham. Beginning at the first stroke of the signal of five bells (sounded by Mr. Putnam), which was to mark an interval of 60^s preceding the computed time of second contact, a count was made at the chronometer beat, starting at 0^s. At 60^s, or at computed second contact, the call was started, again from 0^s. During totality two comparisons were made of the count with the chronometer readings, and two others were made after third contact. A part of the record, including the last two comparisons, is unintelligible, but the later comparisons agree with the second in showing that the difference between the chronometer and the count was a multiple of 5^s. Hence, in the first comparison, although the seconds are recorded as 46^s, they are assumed to be 45^s. The chronometer corrections to reduce to sidereal time of station were computed from comparisons with the Washington noon signals.

OBSERVED TIMES OF CONTACTS, MAY 27.8, 1900, ASTRONOMICAL MEAN DATE.

Contact	Chron. Time.			Correction		Local Sidereal Time			Local Mean Time		
	h	m	s	m	s	h	m	s	h	m	s
1st	23	37	49.	+ 0	33.4	23	38	22.4	19	15	59.5
2d	0	47	03.0	+ 0	33.6	0	47	36.6	20	25	2.3
3d	0	48	30.	+ 0	33.6	0	49	3.6	20	26	29.1
4th	2	7	30.	+ 0	33.8	2	8	3.8	21	45	16.3

Contact	Gr. M. T. Observed			Gr. M. T. Computed		O—C
	h	m	s	m	s	s
1st	0	36	17.4	36	10.	+ 7.
2d	1	45	20.2	45	23.6	— 3.4
3d	1	46	47.0	46	55.6	— 8.6
4th	3	5	34.2	5	43.	— 9.
		1	26.8	1	32.0	— 5.2

No significance is attached to the tenths of a second except in the case of the second contact.

PHOTOGRAPHS OF THE CORONA.

The corona was photographed with eight lenses as described below.

The principal instrument was a horizontal telescope of 61½ feet focus, fed by a coelostat. The 6-inch photographic objective of this telescope was made by Brashear, and gave photographs of the corona on a scale of 13 inches to the degree. The coelostat was constructed in the instrument shop of the Yerkes Observatory under the supervision of Mr. Ritchey, who himself made the very perfect silvered plane mirror of 12 inches aperture. The same mounting carried a 15-inch plane mirror by Petitdidier for Professor Frost's spectroscopic work. The 6-inch objective was connected with the photographic house by a long light-tight tube, shielded from the Sun's rays by a white cotton screen, and fitted throughout with diaphragms to prevent internal reflections. The light-tight photographic house, 6 feet wide and 30 feet long, stood with its long axis perpendicular to the tube. In order to facilitate handling the large photographic plates employed, they were mounted on a wooden carrier 15 feet long, free to move on ball bearings on a steel track extending the entire length of the photographic house. In this carrier the plates were all placed at an angle equal to the latitude, so that the long axis of the plates was parallel to the celestial equator. A catch operated by hand served to stop the carrier at the proper place for each exposure.

With this apparatus seven plates were exposed during totality. Details of these exposures are given in the following table:

No. of plate	Exposure	Size	Make	Remarks
1	½ second	14×17 in.	Cramer D. C.[1]	Not backed
2	2 seconds	14×17	Cramer Crown	Backed
3	8 "	25×30	" "	"
4	30 "	25×30	" "	"
5	14 "	25×30	" "	"
6	4 "	25×30	" "	"
7	1 second	14×17	Cramer D. C.[1]	"

The very sensitive plates employed were made expressly for this purpose by the Cramer Company. They were carefully backed, with a

[1] Double-coated. The first plate was purposely left unbacked.

PLATE VIII

GROUP OF PROMINENCES IN SOUTHWEST QUADRANT

PHOTOGRAPHED WITH A TELESCOPE OF 6 INCHES APERTURE AND 6½ FEET FOCAL LENGTH BY E. E. BARNARD AND G. W. RITCHEY

solution of caramel and burnt sienna in a little alcohol, by Professor Barnard the night before the eclipse and mounted in the carrier. The backing used, which Professor Barnard had adopted after a series of careful experiments, would not dry rapidly in the moist climate of Wadesboro, and had to be protected with pieces of soft paper covering the backs of the plates, which served the purpose perfectly.

The exposures were made with a wooden shutter, which could be moved across in front of the lens by cords leading into the photographic house. Mr. Ritchey stood at the carrier and moved the successive plates into position for exposure. At the signal from him the exposure was made by Professor Barnard, the proper interval being counted from a telegraph sounder beating seconds in the room.

The previously arranged program was successfully carried out. From the adjoining camp of the Smithsonian party the signals at the beginning of totality and 10 seconds before the close were struck on a bell which could be plainly heard in the photographic house. At the first of these signals the exposures were immediately begun. At the last signal preparations were being made for the last exposure, and when the image was seen on the plate the Sun had just made its appearance, though the interval from the signal could hardly have exceeded four seconds.

The plates were developed at the Yerkes Observatory by Professor Barnard with pyro developer, which he had found to give softer and more transparent negatives than any other developer tried. The resulting negatives offer abundant evidence of the advantage of long focus objectives for photographing the details of the corona. The greatest extension of the equatorial corona is about 40′ from the center of the Moon. The whole of the inner corona is well shown, but to bring out extensions of a degree or more would have required an exposure of not less than a minute. The polar fans are shown with remarkable beauty on these plates, and the inner corona is full of detail. In the area covered (1°.9 × 2°.2, the longer direction parallel to the equator and the Sun central), four fixed stars are clearly shown, both on the 14-second and 30-second exposures, while at least two appear on the 8-second exposure. These stars are:

DM. +21°642	4.3 magnitude
+21 643	6.0
+21 647	6.5
+20 751	6.2

It would thus appear probable that no intra-mercurial planet, photographically as bright as the 6.5 magnitude, was in the region covered by the plates at the time of the eclipse.

A discussion of certain important facts brought out in these large photographs of the corona will be published hereafter. Briefly, however, it may be said that there seems to be no very striking connection between the prominences and the coronal details, such as was suggested by the photographs of the Indian eclipse of 1898.

The other instruments used included a 6-inch and a 3¼-inch portrait lens, carried on an equatorial mounting kindly loaned by Professor Comstock of the Washburn Observatory. Three exposures each, of 15 seconds, 30 seconds, and 12 seconds, were made by two gentlemen who kindly volunteered their services, but as the driving-clock did not perform well the image of the corona drifted during the exposures.

Two cameras fixed rigidly to a post, a 4½-inch portrait lens by Brashear and a Voigtländer lens of 4 inches aperture and 8 inches focus, were exposed for 1 second, 2 seconds, and 4 seconds by Mr. Wolff, janitor of the Yerkes Observatory. The Brashear lens gave excellent results, the corona being carried three fourths of the distance to *Mercury* with a single second exposure. The negatives made with the Voigtländer lens are less successful, but the rapidity of the lens is attested by the fact that *Mercury* gave a reversed image with 1 or 2 seconds exposure.

Several photographs of the corona were also secured with smaller lenses, but in no case do the streamers extend more than about three fourths of the distance to *Mercury*. As the images are too small for successful reproduction, Mr. P. R. Calvert has very kindly made an excellent drawing (Plate I) combining the different pictures made with the small instruments with some details supplied from the larger photographs. In this drawing the coronal streamers have not been carried as far out as they can be traced on the small pictures.

Professor Barnard states that a glance at the corona projected on the plates in the coelostat house showed at once that it was almost a duplicate of the corona of January 1, 1889, and the images on the small plates fully confirm this impression. It is evident that this form is characteristic of the period of Sun-spot minimum. The prong-like projection to the east, the wide flaring streamers to the west, and the beautiful polar fans form almost a duplicate of the corona of 1889.

SPECTROSCOPIC RESULTS.

The following slitless spectrographs, supplied with light from the coelostat, after a second reflection, were used by Professor Frost, who was assisted in making the exposures by Dr. George S. Isham:

1. A train of three prisms of very white flint glass (from the new stellar spectrograph), 2¼ inches high, curtate face for 2 inches aperture, set at minimum deviation for λ4227, with total deviation of 182° 30′. The resolving power of the train for this region is about 100,000. Photographic camera objective of 3¼ inches aperture and 42 inches focus. Cramer Crown plates.

The plate-holder was one belonging to the solar spectroscope, and could be moved in a direction perpendicular to the length of the spectrum, so that several exposures could be made on one plate, avoiding loss of time in changing plates. Thus the spectra of the cusp, of the first flash, and of the corona were taken on one plate, and those of the second flash and of the cusp after totality on the second. The plates were cut during development, so that development of the coronal exposure could be pushed further than for the other exposures.

Exposures: Cusp, 15 seconds before totality (½ second), first flash (2 seconds), corona (30 seconds), second flash (about 2 seconds); cusp, 10 seconds after totality (½ second).

2. Concave grating of 60 inches radius; ruled surface ⅞ × 1¾ inches, 14,438 lines per inch. λ4600 (first order) at middle of plate. Cramer Crown plates. Used direct, without slit or image lens.

Exposures: First flash and second flash, each intended to be of about 2 seconds.

3. Plane grating of 2½ inches surface, 14,438 lines per inch, second order, set for the yellow region. Objective of 2 inches aperture and 20 inches focus. Used by Professor Frost for visual observations of the flash, to give the signal for other spectroscopic exposures.

At 45 seconds before totality the dark lines were very sharply defined in the quite limited field of view of the eyepiece. The bright helium line D_3, showing prominences, was seen perhaps 10 seconds before totality, and other lines appeared in succession as totality approached. There was, however, no such multitude of lines reversed as had been expected by the observer, some fifteen or twenty lines being visible when the observer gave the signal for exposing the objective-prisms and concave grating, and himself made the exposure for the red portion of the spectrum.

4. Plane grating of 5 inches ruled surface, 20,000 lines per inch, used in first order, in front of a visually corrected lens of 3½ inches aperture and 42 inches focus, for photographing cusp and flash spectra in the red portions of the spectrum with Erythro plates. A rather too thick color screen of red glass was inserted for cutting off the overlapping violet of the next order.

Exposures: First flash (about 5 seconds), corona (55 seconds), second flash (7 seconds), cusp after totality (½ second).

First flash.—On the photograph taken with the prism train 70 bright lines have been measured between λ4070 and λ4340. No dark lines are shown on the plate. The concave grating negative shows about 70 measurable bright lines between $H\beta$ and $H\delta$, and no dark lines.

Second flash.—On the photograph taken with the prism train 266 bright lines have been measured between λ4026 and λ4381 (Fig. 1, Plate IX). Some dark lines are visible, especially at the violet end of the plate. The bright lines are there found to be at the violet edges of the dark lines.

In attempting to determine the identification of the lines from Rowland's list of wave-lengths the following points are noted:

There is a marked dissimilarity from the solar spectrum, particularly in regard to the intensities.

A large number of the identifications which appear most probable are found to be with lines designated in Rowland's list as *N*, or *N d?;* that is, with lines which are nebulous or are difficult doubles. Professor Frost suggests that the nebulous character of these dark lines may be due to the superposition of the chromospheric light, and that the duplicity may possibly be on account of a reversal at the center of the dark line.

Aside from the lines of hydrogen and helium, the identification seems to be certain for numerous lines of iron, titanium, chromium, and several of calcium, strontium, vanadium, and zirconium. High level and low level lines can be to some extent differentiated by the length of the bright arcs.

The concave grating negative of the second flash shows about 150 lines, 110 between $H\gamma$ and $H\delta$ in sharp focus. The bright lines generally seem to be on the violet side of the dark lines, with some exceptions.

Cusp at first contact.—The negative taken with the prism train shows a small number of bright lines superposed upon the strong solar

PLATE IX

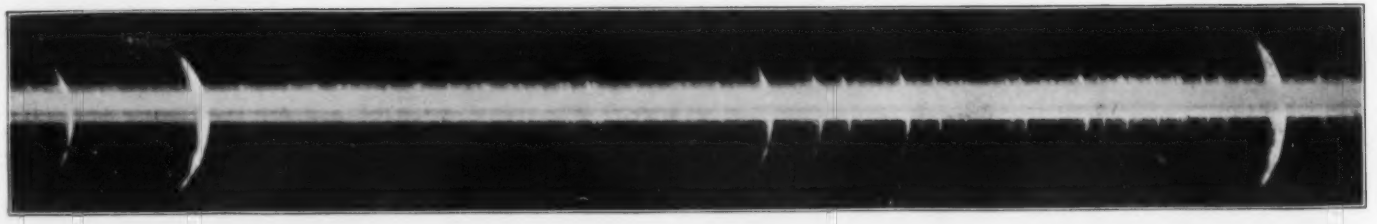


FIG. 1.—THE FLASH AT THIRD CONTACT

FIG. 2.—THE CUSP TEN SECONDS AFTER TOTALITY

SPECTRA PHOTOGRAPHED WITH OBJECTIVE-PRISM TRAIN BY E. B. FROST

spectrum. Several strong lines near the middle of the plate indicate that the bright lines are on the violet side of dark lines. At the ends of the plate, however, the displacement would appear to be in the other direction, at least in the case of several lines.

Cusp at second contact.— About 250 bright lines between λ 4058 and λ 4375 have been measured in this cusp spectrum taken with the prism train (Fig. 2, Plate IX). Many of the bright lines appear to fall on the violet edge of the dark lines. Direct comparison of bright and dark lines shows marked dissimilarity between them.

Corona.— The plate exposed for the coronal spectrum with the prism train shows an intense continuous spectrum, and parts or the whole of seven rings, the wave-lengths corresponding to which are: λ 4078 (chromospheric), *Hδ*, λ 4216 (chromospheric), λ 4230 (coronal), λ 4311 (probably chromospheric), *Hγ*, and λ 4358 (perhaps coronal).

The exposures on the red portion of the spectrum, with plane grating, were insufficient, partly on account of the absorption of the color screen and partly on account of the less degree of sensitiveness of plates for these wave-lengths. The cusp spectrum shows a few dark and bright lines.

HEAT RADIATION OF THE CORONA.

Through the kindness of Secretary Langley the bolometric apparatus, with which the writer, assisted by Mr. Ellerman, intended to measure the heat radiation from the bright and dark parts of the corona, was used in conjunction with an 18-inch coelostat mirror mounted on the large siderostat of the Smithsonian party. The image of the corona was formed by a 20-inch silvered concave mirror, of 27 feet focus, made in the optical shop of the Yerkes Observatory by Mr. Ritchey. In the cardboard disk on which the image fell was a radial slit, 10 mm long and 1 mm wide, which could be rotated in position angle so as to receive radiations from any part of the inner corona. By means of a suitable combination of mirrors an image of the slit, formed on the fixed bolometer strip by a quartz lens placed beyond the principal focus of the concave mirror, was automatically kept from rotating when the disk revolved. The bolometer, which had to be made in Wadesboro a few days before the eclipse (on account of a serious change in resistance of the old bolometers while in transit from Williams Bay), was 10 mm long and 1 mm wide. The very sensitive galvanometer (figure of merit about 3×10^{-10}) was one made by Professor C. E. Mendenhall, who kindly loaned it for this occasion.

With a period of 5 seconds, and a battery current of 0.3 amperes through the bolometer, this apparatus gave a deflection of about 20 mm for a candle at a distance of 3 m from the bolometer strip with no lens or mirror interposed.

The apparatus was in perfect adjustment just before totality, but at the critical moment an accident disturbed the balance of the bolometer circuit, and sent the spot of light off the scale. The work of rebalancing the circuit was completed during the total phase, but just as the signal was given to expose the Sun reappeared. During the succeeding partial phase a large number of measures were made of the heat radiation of the sky near the Sun. Like many similar measures made at Williams Bay in previous years, they show no certain difference between the radiation of corona plus sky and sky alone. Fortunately Mr. Abbot's measures of the heat radiation of the corona explain this, and as they also answer the question which had led to our own eclipse work, its failure is of less consequence. The deflection which he obtained from the corona (as compared with the dark Moon) was very small—much smaller than had been anticipated. The bolometric apparatus used in our work at Wadesboro, as well as that of previous experiments, was rather more sensitive than that employed by Mr. Abbot, but the angular aperture of our concave mirror, and consequently the intensity of the (larger) solar image, has always been much less than his. Thus in our observations the difference between corona plus sky and sky alone has never been great enough to be detected. Further experiments, made in the hope of measuring in full sunlight the position angle of the edges of the great coronal streamers with an extremely sensitive radiometer, are now in progress at the Yerkes Observatory.

Arrangements had been made to photograph the chromosphere and prominences at the Yerkes Observatory at the time of the eclipse with the spectroheliograph attached to the 40-inch telescope, but clouds prevented.

ACKNOWLEDGMENTS.

It is a pleasure to be permitted to express our sincere thanks to all who contributed to the success of the expedition. We are indebted to the mayor and citizens of Wadesboro, who made every possible provision for our comfort and welfare during our stay in North Carolina;

to Mr. John Leak, for the free use of the land on which our instruments were erected; to Secretary Langley, for the use of the large Smithsonian coelostat, and for many other courtesies; to Mr. O. W. Potter, Mrs. H. M. Wilmarth, Mrs. George Sturges, Mr. Samuel Allerton, Mr. J. H. Moore, and Mr. M. A. Ryerson, for contributions to the eclipse fund; to Dr. George S. Isham, who not only contributed to the fund, but accompanied the party and gave most valuable assistance in the work of preparation and on the day of the eclipse; to the officials of the Chicago & Northwestern Railway Co., and particularly to General Traffic Manager H. R. McCullough, who furnished free transportation for the members of the party and their instruments over the line of this company, and assisted us in other ways; to Mr. C. G. Abbot and other members of the Smithsonian party, whose aid and advice were of great value; to Professor C. E. Mendenhall, for the use of an excellent galvanometer, set up and adjusted by himself; to the U. S. Weather Bureau, for daily weather bulletins; to Professor Flint, Professor Goodwin, Professor Laws, Professor Noyes, and other gentlemen who kindly volunteered their services; to Mr. P. R. Calvert, for the beautiful drawing of the corona reproduced in Plate I; to Mr. S. C. Reese, Mr. S. B. Barrett, and Mr. C. E. Rood, for solar observations made at the Yerkes Observatory during the absence of the eclipse party; to Professor George C. Comstock, Mr. J. A. Brashear, Mr. William Gaertner, Mr. O. L. Petitdidier, and the Vanderbilt University, for the use of instruments; to the Chicago Color Photo Co., for a supply of Erythro plates; to Mr. William Braisington, building contractor at Wadesboro, who not only erected our buildings in a very satisfactory manner, but rendered much additional assistance without compensation; and to many others whose aid was hardly less important. It is proper to add that the results briefly referred to in this *Bulletin* are primarily due to the energy and enthusiasm with which each member of our party performed the task entrusted to him.

GEORGE E. HALE.

July 23, 1900.

OBSERVATIONS OF THE TOTAL ECLIPSE AT CENTREVILLE, NORFOLK CO., VA.

THE observers from Brown University, Providence, who were joined by several from Boston, located at Centreville, twelve miles south of Norfolk, Va. The approximate position of the station is long. 76° 11′, lat. 36° 41′. Transit and zenith telescope observations for more exact position were made.

The equipment consisted of two 4-inch visual telescopes, one of which (a Brashear lens) was reduced to a 3-inch and used for a photographic telescope; an equatorial stand driven by clockwork, upon which the Brashear telescope was placed and also a 3-inch Clark lens with focal length 135 inches and a 3-inch Allen lens with focal length 77 inches; a prismatic camera with flint prism of 60° in front of a 2.5-inch telescope with focal length 38 inches; four cameras with apertures ⅞ inch to 3 inches and focal lengths 6.5 to 22 inches.

The chief observations planned were visual observations of the times of contact and a special study of the coronal region near some conspicuous prominence; photographic observations of the solar crescent during partial phases, and of the corona especially for its extensions, search for possible intra-mercurial planets.

The contacts were observed by W. Upton and W. S. Meader. The duration of totality was observed to be 99 seconds, instead of 101 or 105 seconds as calculated for the approximate position of the station by the tables of the American and English Almanacs respectively. The second contact preceded the calculated time by three seconds.

The visual study of the corona in the vicinity of a prominence was made by W. Upton with a 4-inch telescope, power 60. Attention was confined entirely to the great prominence in the southwest quadrant. A very careful scrutiny of the corona showed no trace whatever of any hood or distortion of the corona in its vicinity. The structure was radial and there were several folds one upon the other at a distance half a diameter and greater from the Sun's limb, very much as represented in the combined photograph of the 1878 eclipse published by the United States Naval Observatory. The polar streamers and the equatorial extensions of the corona were casually noted, and the corona resembled in general that of 1878 observed at Denver with a telescope of 5 inches aperture.

The equatorial stand was in charge of J. Edwards. With the 4-inch Brashear telescope, fifteen successful exposures were made during the first partial phase and twelve in the second partial phase. These were made with a rapid moving drop shutter containing a narrow slit. The negatives show sharp outlines for the crescent, and can be used for determining the relative position of Sun and Moon. Ten of the plates in each series are at exactly corresponding times before and after totality. During totality six exposures were made in the corona with times varying from 1 to 20 seconds. The best detail is shown on

the plates with times 5 and 8 seconds, both of which were made on Seed's orthochromatic plate. The other plates were special triple-coated plates made by Seed. All plates were backed with Bostwick's anti-halo. Immediately after totality seven exposures were made from ½ to 4 seconds, and extending to 50 seconds after third contact. All show the coronal outline which could have been photographed longer. This apparatus was in charge of H. D. Kenyon, assisted by E. A. Kenyon.

The long focus lenses on the equatorial stand were used upon a region extending 13° west and 18° east of the Sun along the line of its equator. Four 8×10 plates were placed side by side in the holder adapted to the Clark lens and three in that of the Allen lens (which has the shorter focus). The width of the belt photographed was 4° for the former and 7° for the latter lens. The proper curvature for each lens was determined by experiment. The plates were Seed 27. An exposure of 60 seconds was given the Clark and 20 the Allen lens, and a supplementary exposure of 15 seconds was given each. None of the plates were fogged by excessive exposure and all have been successfully developed. The images drifted somewhat, giving trails instead of dots. Mercury is prominent and there is much detail in the coronal images, but no stars have been found in the first examination. These cameras were managed by J. Edwards, assisted by N. B. Whitaker, and by Messrs. T. Sawyer, F. L. Lilley, W. K. Wood, D. W. Wood, and W. W. Cooper, of Centreville.

The prismatic camera was managed by F. Slocum, the exposures made upon an Eastman film in a roll holder. Several quick exposures were made before and after totality, one each at the times of second and third contact, and three during totality of 15, 35 and 10 seconds respectively. Many lines are upon the plates, both dark and reversed, and the chief chromospheric lines are prominent. A faint continuous spectrum was obtained during totality.

The smaller cameras were in charge of H. P. Abbott, O. B. Cole, Mrs. Cole, Mrs. Slocum, and S. M. Wright, of Centreville. Six exposures were made with a Darlot lens of 22 inches focal length, $\frac{f}{a} = 16$, with times from 3 to 20 seconds; four each with a Darlot and a Dallmeyer lens of 12½ inches focal length, $\frac{f}{a} = 8.3$ with times 10 to 20 seconds, equivalent to 33 to 66 for $\frac{f}{a} = 15$; three with a small

camera of 6½ inches focal length, $\frac{f}{a} = 7.4$ with times 8 to 30 seconds, equivalent to 33 to 120 seconds. Many of these plates are excellent, showing extensions out to 3 diameters from the Sun. The eastern wing of the corona shows one or two subsidiary extensions in addition to the chief projection, and the first tail on the west has several projections between the two marking its northern and southern boundaries.

Meteorological observations were made by O. B. Cole and the shadow bands were noted by J. Ritchie, Jr., and E. F. Sawyer. An attempt to photograph the bands was made by Miss M. F. Babcock. The temperature fell 8° and recovered somewhat slowly. The wind was very light and veered gradually from S.E. to S. There was little evidence of any fluctuation ascribable to the eclipse. The shadow bands were seen two minutes before and after totality and their forms and directions carefully marked upon white sheets placed on the ground. They were very faint, about an inch in width and with a space of an inch between them. They had an irregular convex front and moved with a quivering, unsteady motion. Before totality they moved towards N.E. by E., and after totality towards E.N.E. Their velocity was estimated to be five to ten feet per second.

The time was called each 10 seconds by R. K. Hyde, who also recorded the times of the contacts and of exposures. A metronome marked seconds. No hitch occurred in carrying out the program planned.

The members of the expedition were hospitably accommodated by Dr. W. Keeling Wood, of Centreville. The Western Union Telegraph Company, the Norfolk and Southern Railroad, and the Merchants' and Miners' Transportation Company were especially attentive to the needs of the expedition. The weather was perfect. A heavy dew had fallen the night previous, but none was noted during the eclipse. The sky was cloudless and there was almost no wind.

WINSLOW UPTON.

OBSERVATIONS AT JULIETTE, GA.

THE station occupied by our party—Juliette, Ga.—is on the Southern Railway between Macon and Atlanta, being about twenty-three miles northwest of Macon. Its approximate latitude and longitude are 33° 6′ N. and 83° 48′ W. of Greenwich.

The party consisted of the writer, in charge, Professors W. H. Kilpatrick and W. E. Godfrey, of Mercer University, with several of their students, C. A. Caldwell, Thomas Harrold, Rev. John G. Harrison, O. H. Crockett, Roy W. Crockett, and Mrs. C. W. Crockett. At Juliette we were joined by two amateurs, H. Fritz and H. L. Smith, of Chattanooga, with a 2-inch telescope.

The work was assigned as follows:

The writer with a 3½-inch equatorial, and Professor Kilpatrick with a 4-inch, were to note the times of contact and to make drawings, if possible, each of half the inner corona.

Professor Godfrey, P. J. Christopher, and J. B. Henson were to watch the timepiece.

Messrs. Caldwell, Harrold, Christopher, and Godfrey were to draw each one quadrant of the corona, as seen with the naked eye.

Messrs. Fritz and Smith were to note the times of contact and to make sketches each of half the corona.

Mrs. C. W. Crockett was to make a drawing of the entire corona, as seen with the naked eye.

O. H. and Roy W. Crockett were to observe the shadow bands.

Rev. Mr. Harrison was to note the temperature.

The sky was cloudless and the observations satisfactory. The reports have not been collected, but some of the results are given below.

1. *The times of contact.*—The times noted by Professor Kilpatrick and myself agreed within a second for the first two contacts; the third contact he failed to get, studying as he was the other limb of the Sun; in the last contact his records showed a time later by perhaps twenty seconds than mine. My eyes were fatigued by the strain, as I commenced looking earlier than was necessary; otherwise I know of no reason that would lead me to doubt my recorded time. We also noted the time when the Moon's eastern limb bisected the spot at the vertex of the angle formed by the Sun-spots. My results were as follows:

	Watch times	Correction	90th meridian times
	h m s	m s	h m s
First contact	6 35 01	−3 8.9	6 31 52.1
Bisection of spot	6 56 42	−3 9.0	6 53 33.0
Second contact	7 41 59	−3 9.4	7 38 49.6
Third contact	7 43 17	−3 9.4	7 40 7.6
Fourth contact	8 59 30	−3 10.0	8 56 20.0

2. *Shadow bands.*—A sheet was spread horizontally, the corners being tacked to stakes driven in the ground. The observers reported that the bands were about the width of a man's hand, wavy and indistinct, and that it was impossible to count them.

3. *The temperature* fell decidedly during the eclipse, the fall during totality being about a degree Fahrenheit.

4. *Inner corona.*—Two interesting features on the western half of the Sun's limb were noted by me — using a 3½-inch glass with a power of about 40. One was the polar radiating streamers, the other a petal shaped formation about 90° from the solar vertex. In my drawing a prominence is shown at the center of the base of the petal; the petal itself was brightest at its boundaries, but otherwise, so far as I noted, it was without peculiarities.

5. *Brightness.*—I have been accustomed to observing the Moon with the same telescope and eyepiece, and in my judgment the intensity of the light from the inner corona is less than that from the Moon.

6. *Outer corona.*—A sketch was made by Mrs. C. W. Crockett, and the members of the party expressed themselves as considering it a good representation of the corona as it appeared to them.

7. *Mercury* was seen. Some one of the party said that another heavenly body was visible, and I am seeking more definite information.

C. W. CROCKETT.

RENSSELAER POLYTECHNIC INSTITUTE,
July 2, 1900.

OBSERVATIONS OF THE TOTAL SOLAR ECLIPSE OF MAY 28, 1900, BY THE HARVARD OBSERVATORY EXPEDITION.

THE plans of the Harvard Observatory Expedition involved (*a*) the search for an intra-mercurial planet; (*b*) the securing of some satisfactory photographs of the inner corona; (*c*) the securing of photographs of the outer corona; (*d*) actinic measures of the brightness of the corona, sky, and Moon; (*e*) shadow band observations; and (*f*) visual measures of the minimum size of the polar filaments.

The intra-mercurial apparatus was of considerable mass and bulk, measuring in general 6×6×11 feet, and together with the telescopes for photographing the inner corona, and two of the actinometers, was carried on a mounting formerly used to support the Clark 12-inch telescope. The other instruments were mounted separately, without

clockwork. There were in all nineteen cameras, one 4-inch and one 5-inch visual telescope. As I had only one assistant from the Observatory, Mr. W. H. Attwill, available for photographic work, it was necessary to employ native help. At previous eclipses this plan had worked very well, but in the present instance it proved unfortunate, for although every one had been carefully instructed on no account to touch the telescope while the exposure was being made, yet a native assistant becoming excited changed a plate-holder almost at the very beginning of the exposure, so jarring the instrument that all the plates taken with it were a total failure.

Our photographs obtained with the other instruments of the outer corona proved very successful, as did those taken for the purpose of determining its brightness. These have not as yet been measured. No results can therefore be given until they have been reduced, but it may be said that they fully confirm the general impression derived from visual observations that this eclipse was an unusually bright one.

Mr. J. R. Edmands recorded the time of appearance of the shadow of the Moon upon the sky, and of other shadow bands upon the screen, before second contact, and observed the time of disappearance of the bands after third contact. He noted that they were spaced about four inches apart, or nine to the yard; also that they had length, but no describable shape or curvature. He observed also the time of fourth contact.

It seemed to the writer to be a matter of general importance to determine if the photographs showed all the visual detail that there was in the corona, or if, as in the case of the Moon and planets, still finer detail existed which our present photographic appliances were unable to portray. This seemed the more important since very delicate visual detail had been reported at the eclipse of 1878. A ½-inch eyepiece was therefore prepared, furnished with two cross wires, one of silk and one of glass, subtending angles, as seen in the telescope, of 1″ and 6″ respectively. After a careful examination of the polar filaments only one could be found that was as fine as 6″ in diameter, although the definition was such that, had any existed subtending as small an angle as 1″, it would certainly have been detected. My conclusion, therefore, is that the better class of photographs should show all the fine detail that can be seen with our present visual appliances. I observed also the times of first and fourth contacts.

WILLIAM H. PICKERING.

HARVARD OBSERVATORY,
Cambridge, Mass., June 30, 1900.

OBSERVATIONS OF THE TOTAL ECLIPSE BY THE VASSAR COLLEGE PARTY.

THE two observers of the eclipse from Vassar College selected Wadesboro as their station and were situated on Carr's Hill an elevation outside the town limits. A 3-inch Clark telescope and a pair of 2-inch field glasses with a direct vision spectroscope attached to one eyepiece were the instruments used. The observations planned for were (4) and (7) of the Eclipse Committee Circular of March 29, *i. e.* color of prominences and distribution of coronium. Miss Furness, who observed the prominences is familiar with the appearance of the prominence as seen in the spectroscope. The eyepiece of telescope was provided with cross-wires for location in position angle, and these were oriented during partial eclipse by the motion of a Sun-spot. The power was sufficiently low to allow the whole rim of the Moon to be seen. No white prominences were observed, but all were of the usual rose color with one exception. A triangular-shaped prominence about the middle of the S. E. quadrant appeared to be somewhat more pinkish than the others.

The direct vision spectroscope attached to the field glass was a McClean star spectroscope with the cylindrical lens removed. The apparatus was tested as suggested in Professor Hale's article in the January number of the ASTROPHYSICAL JOURNAL. The observation during totality was, however, without satisfactory result. The chromospheric rings with the larger prominences were clearly and beautifully seen in several colors, but the continuous spectrum of the corona was so bright that the green coronium image could not be separated from it. I conclude that the dispersion of the prisms was not sufficient. The inner corona was much brighter than I had expected.

MARY W. WHITNEY.

OBSERVATIONS BY THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY PARTY.

THE Institute of Technology party in Washington, Ga., did not contain any observer who could properly be called an astronomer, and there was no attempt made at original research.

The Institute party first determined the latitude and longitude of the station. (A solid brick and cement pier marks the point.)

Observed latitude, N 33° 43′ 49″
Observed longitude, W $5^h\ 30^m\ 56^s.2$

The four contacts were observed as follows (*mean local time*):

1st contact -	-	7^h	02^m $22^s.7$
2d "	-	8	09 52.0
3d "	- -	8	11 18.2
4th "	-	9	28 26.9

G. L. HOSMER, Observer.

We tried to do this part of the work as well as possible, and our outfit was quite complete for time and latitude observations.

Six fairly good photographs were taken by Harrison W. Smith with a special camera devised by him, and several fairly complete sketches were made. (Half-tone reproductions of photographs and sketches will be given in the July number of the *Technology Review*.)

Observations were made with the magnetometer on the day of the eclipse to see if any disturbance in declination could be detected. The magnetometer readings showed only the normal daily variation.

The Institute of Technology party made a small plan showing location of station with reference to nearest house and road, observed the dip and declination of magnetic needle and established a meridian line.

ALFRED E. BURTON.

OBSERVATIONS AT WADESBORO, N.C.

THE eclipse was observed at Wadesboro, N. C. A 2-inch and a 3-inch refractor, with powers 9 and 28 respectively, were mounted together upon one axis. The entire period of totality was given to observation, notes and sketches being made after third contact before leaving the observing chair. A very careful search for white prominences in both glasses convinced me that none were present.

I recorded the "impression" that the red prominences were not all of the same shade, and, later, added the note that the red was, in general, lower than at *Hα*. The polar streamers, hurriedly observed, were seen as discrete filaments, symmetrically disposed at each pole, estimated to have a radial altitude of from one fourth to one third of a solar diameter. The equatorial corona was continuous along both limbs, and presented no peculiar variations or curvature save at one point, viz., east and a little north from the *double* prominence that appeared upon the east limb, distant three, or it may be five, times the altitude of the prominence, there was a place where the corona showed

a decided curvature, concave as viewed from the south. The appearance was not that the entire body of the corona was curved at this place, but as though a part nearer the observer was curved, while the main body both around and back of it continued in the same general unbroken manner. This appearance was distinctly noted twice.

On comparative brightness I find only this note: "My impression is that, immediately next to the limb, the equatorial part was not as bright as a little higher up, say up one eighth of Sun's diameter."

When the photosphere (white) reappeared at the west limb, I began to count seconds and watched the corona through the 2-inch *close* at the east limb of the Moon. The bright crescent of the photosphere was approximately in the center of the field. I counted eleven seconds while the corona was still seen immediately at the east limb, the vision being entirely averted once or twice during the count.

The corona at this limb, during perhaps the last four seconds, appeared as discrete spikes and seemed to be lost, not by their fading out, but by the Moon moving on and occulting them.

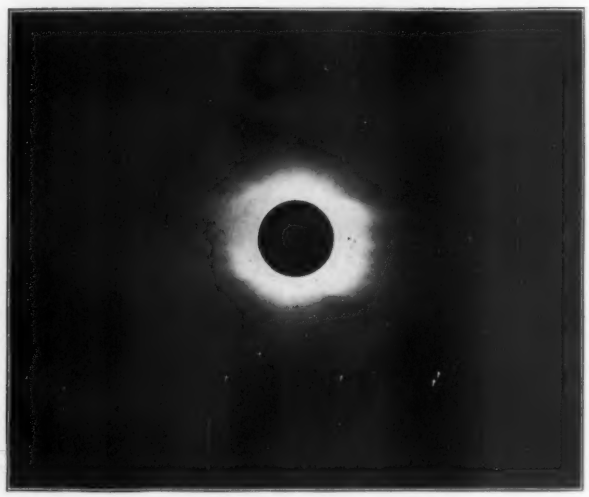
J. B. Coit.

OBSERVATIONS AT SOUTHERN PINES, N. C.

Our eclipse party, which consisted of Mrs. George A. Seagrave, Mr. C. A. R. Lundin, and the writer, occupied a site kindly offered by Mr. J. H. Tilghman, at Southern Pines, N. C.

Mr. Lundin had charge of the photographic work, and used a Clark 4-inch photographic telescope of about five and one half feet focal length, mounted equatorially. The writer took with him two small telescopes, one of three and another of two inches aperture; and a sidereal chronometer, Victor Kullberg 1178. Monday morning was clear and favorable. According to the computations of the writer the first contact would take place at (May 27) $19^h\ 19^m\ 36^s$ Southern Pines local mean time, supposing that $\lambda = +79^\circ\ 20'$, $\phi = +35^\circ\ 15'$. At just four minutes before the computed time of first contact I turned the three-inch to the Sun. Mr. Lundin used a two-inch. The seeing was good. As the time drew nearer I drew my attention more closely to the computed position angle of contact, and at $0^h\ 13^m\ 28^s$ by Kullberg I could see the Moon's limb just notching the western limb of the Sun. Mr. Lundin noted it at $0^h\ 13^m\ 28^s.5$. From the time of first contact until totality the writer was busy in observing the gradual

PLATE X



THE CORONA

PHOTOGRAPHED WITH A 4-INCH TELESCOPE BY C. A. R. LUNDIN

advance of the Moon over the Sun's disk with the three-inch telescope. The Sun's surface showed no distortion whatever which could be attributed to a lunar atmosphere. The small spots retained their shape as they were covered by the slowly advancing limb. Mrs. Seagrave, with one or two other observers, saw the shadow bands from three to six minutes before totality. Several white sheets were spread upon the ground, but they were easily seen without them. At three minutes before totality the entire outline of the Moon was visible, and the corona was very brilliant and was composed of many very long streamers. Four very large prominences were seen, and were of a rose color. The corona resembled the one of 1878, and extended from the Sun in the direction of the ecliptic. Mr. Lundin secured six photographs of the corona during totality (Plate X). Each plate was exposed about two seconds. The corona and prominences were visible fully two minutes after totality. The times of the four contacts as observed by me with Kullberg 1178 are as follows:

Providence mean time	Greenwich mean time
$1 = 0^h\ 13^m\ 28^s$	$1 = 0^h\ 36^m\ 50^s$
$2 = 1\ 23\ 20$	$2 = 1\ 46\ 33$
$3 = 1\ 24\ 56$	$3 = 1\ 48\ 9$
$4 = 2\ 44\ 53.5$	$4 = 3\ 7\ 55$

F. E. SEAGRAVE.

THE WEATHER BUREAU OBSERVATIONS OF THE TOTAL ECLIPSE OF MAY 28, 1900.

PROFESSOR WILLIS L. MOORE, as Chief of the Weather Bureau, assigned to Professor F. H. Bigelow the duty of collecting and studying the data showing the probable state of the sky along the path of totality, and several reports on this subject were published, concluding with Weather Bureau *Bulletin* No. 27, "The Probable State of the Sky," etc. The further duty of preparing instructions for meteorological observations to be made during the eclipse was assigned to Professor Bigelow and all the reports received from Weather Bureau observers are now in his hands for discussion and report. He states that there will be between thirty and forty sets of good observations on the shadow bands and from fifty to seventy-five records of special meteorological observations. His report will especially dwell upon the shadow bands and on meteorological matters but will include methods of economically mounting telescopes for photographic work, as illustrated by the

apparatus devised for his own 4-inch refractor. Professor Abbe's report will include sketches of the outer corona by eight or ten different individuals — not Weather Bureau observers. He will also report upon the special observations made by him at Newberry, S. C., on the polarization of blue sky light and on the polarization of the light of the outer corona, as observed by his son, Professor C. Abbe, Jr., of Winthrop College, Rock Hill, S. C. A drawing of both the inner and outer corona made by Professor Very differs entirely from the simple conical sheaf of straight lines of light drawn by Professor Abbe and others, and which outer corona Professor Abbe attributes to streams of illuminated meteoric matter circulating around, or moving past, the Sun. Professor R. A. Fessenden is said to have made some interesting observations on electric disturbances simultaneous with the reappearance of the sunlight.

OBSERVATIONS AT NORFOLK, VA.

My observations were made at Norfolk, Virginia, with a telescope of 4cm aperture, magnifying 17 diameters. A surprising amount of detail appeared in the corona. The complexity was too great to be fully grasped in the galloping seconds, but I had no difficulty in verifying every kind of structure and form which the best photographs of the eclipses of 1878 and 1889 have shown. The diverging sheaves of polar coronal filaments, ten or twelve at each pole stronger than the others, were distinctly traced through a length of 15′ to 20′ until they merged in a structureless haze which paled gradually into the darkness of the surrounding sky. Strong prominences were seen in the southwest and southeast quadrants, the former (some 4′ high) inclined from the radius towards the south pole, the latter (a little on the east side of the south pole) straight, acutely pointed, and radial; besides several smaller prominences. The chromosphere and prominences stood out in vivid brightness, almost as if with a metallic sheen as of ruddy gold or burnished copper, on the silvery white background of the corona. The equatorial wings were still bright at ½° from the limb, but fading away with that gradual diminution of intensity which is perhaps described by the epithet "pearly," expressing a peculiar translucent quality as applied to luster.

A photograph of 20 seconds' exposure, taken by Professor R. A. Fessenden, shows a narrow, straight ray making an angle of about 40°

with the northernmost of the eastern equatorial wings and 79° from the vertex on the east side, nearly tangent to the Sun's limb in the southeast quadrant. The total distance between the fading extremities is about 2° 12′, the ray being equally brilliant on either side of the corona.

Professor Fessenden, assisted by Mr. A. H. Thiessen, attached a Marconi coherer to a wire stretched from a glass insulator at the end of a 10-foot pole projecting horizontally from a tower at a height of 48 feet above the ground, the wire being carried thence diagonally southeast to the coherer, which was very perfectly grounded. Only momentary clicks were noted during the last half hour before totality, but upon the return of the light, the instrument chattered continuously for 20 or 30 seconds.

Only naked eye observations were made by the other members of our party. Mrs. Fessenden saw the planet *Mercury* but no stars. Through the telescope, the streamers remained visible for 3 or 4 seconds after the end of totality, and the inner corona, with a breadth of 2′ or 3′ of arc, for fully 4 minutes longer.

FRANK W. VERY.

U. S. WEATHER BUREAU STATION,
Rock Point, Charles Co., Md.

OBSERVATIONS BY THE GEORGETOWN COLLEGE PARTY.

THE Georgetown College party, at a station south of Norfolk, Va., confined its program to visual observations with opera glasses and to experiments with two small cameras. The following facts were established:

(1) The light of the corona was strong enough to show the entire disk of the Moon half a minute *after* totality.

(2) The *actinic* power of the two large prominences was very much stronger than that of the planet *Mercury*, although *visually* the latter seemed considerably brighter than the former. The planet was identified by a triple image in the shape of a small triangle, produced by slightly touching the camera twice during a four second's exposure.

(3) The sky remained *brighter* than a full Moon night. This was found from reading different types at given distances.

J. G. HAGEN, S. J.

PERSISTENCE OF THE CORONA AFTER TOTALITY.

THE Dickinson College eclipse party took with them a 5-inch equatorial telescope of eighty-six inches focal length for photographing the corona. After developing the pictures taken our negatives show that the corona persists after totality. We were situated at Pungo, Va., very near the central line of totality. The sixth picture taken shows the corona with streamers about one diameter in length, and the inner corona and prominences much over-exposed. The seventh picture shows the corona much less in extent and the crescent of the reappearing Sun. The eighth picture shows the corona all around the Sun and a larger crescent. Now, the *best* time made, *in practice*, in changing plates was ten seconds and usually the time was about twelve seconds. Picture number seven was taken *after* totality was over, and number eight was exposed *at least* ten seconds after that, and probably the exposure was as much as fifteen seconds after the Sun reappeared.

JOHN FRED MOHLER.

DICKINSON COLLEGE,
July 2, 1900.

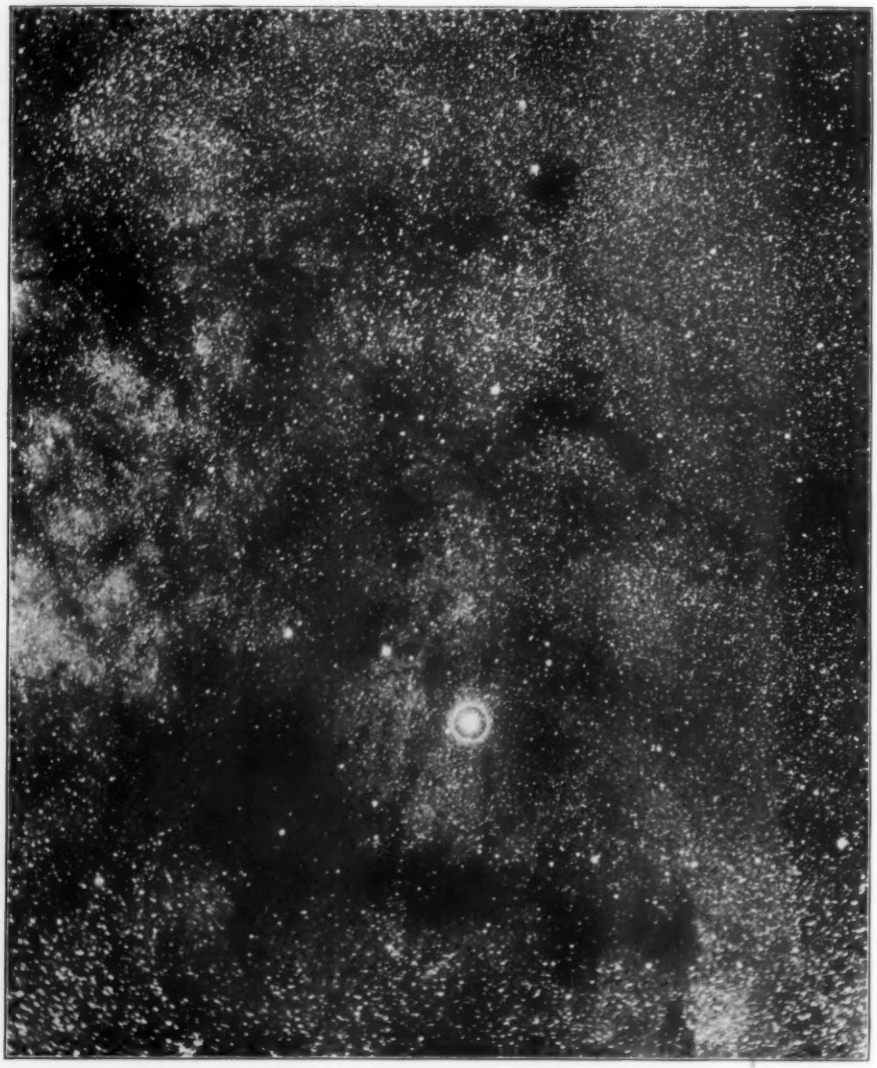
JAMES EDWARD KEELER.

Two years have scarcely elapsed since an announcement appeared in this JOURNAL of James Edward Keeler's appointment as Director of the Lick Observatory. His excellent judgment, high scientific ability, and exceptional breadth of view fully warranted at that time a prediction of success which has already been more than realized. And now, with the task of reorganizing the work of the Lick Observatory admirably achieved, and the Crossley reflector yielding unequaled photographs of star clusters and nebulæ as the direct result of his individual labors, the sad news comes that he passed away on August twelfth. The news was wholly unexpected, for while it was known that he had been suffering from a severe cold, there had been no intimation that any serious outcome was even remotely feared.

Pending the preparation of an adequate account of his life and work I can only add that the loss to astrophysics, to the Lick Observatory, to this JOURNAL, and to many of us personally, will be simply irreparable.

GEORGE E. HALE.

PLATE XI



PHOTOGRAPH OF THE MILKY WAY NEAR THE STAR *THETA OPHIUCHI*